NCO Conceptual Framework Case Study* Template Illustrative Example

* Adapted from the RAND Air-to-Air Case Study

Agenda

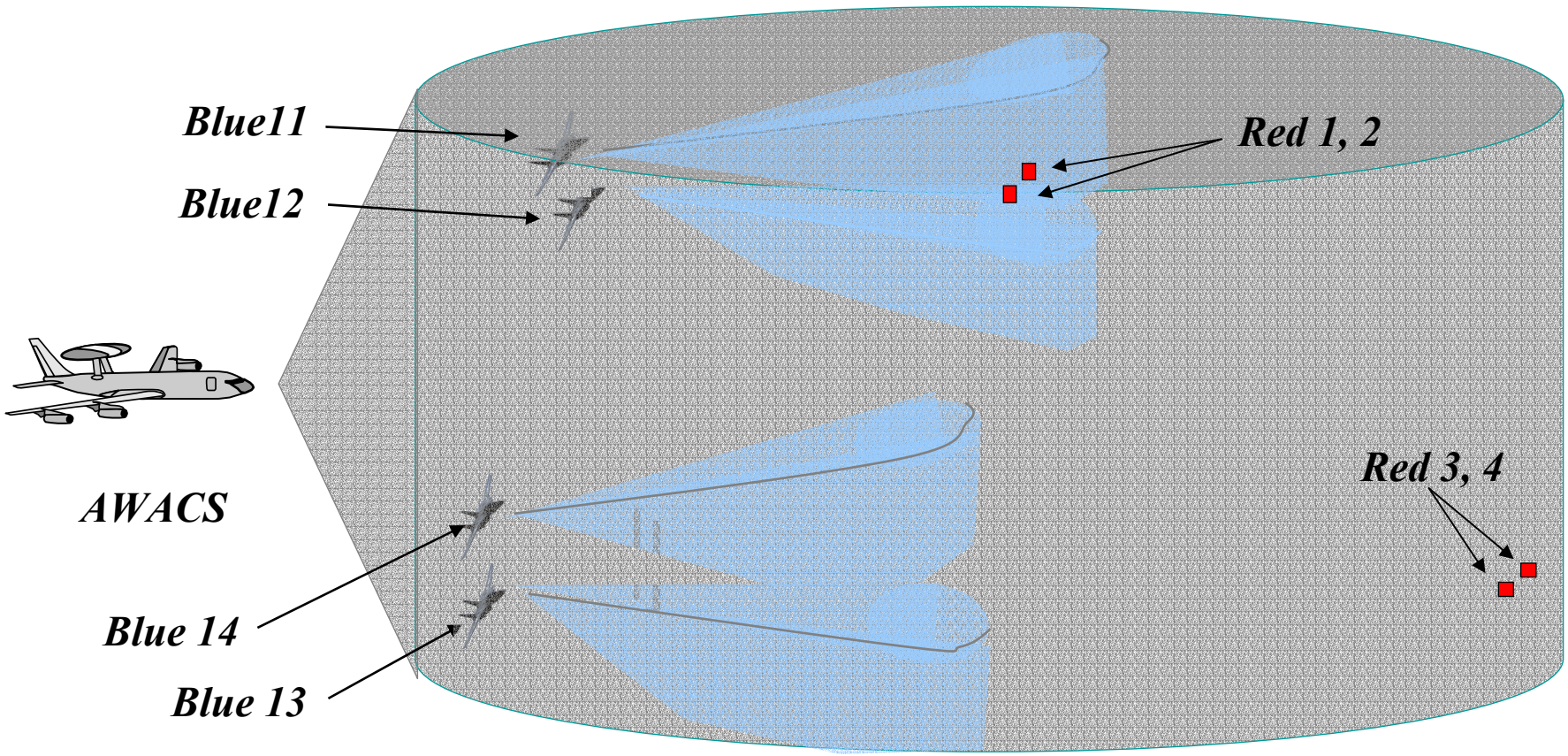
- Case Study Background
- The Bottom Line Result
- Problem Formulation
- Solution Strategy
- The Way Ahead

Case Study Background

- Operational Environment
  - What: Small Air-to-Air Engagements*
  - Where: On Test Ranges
  - When: 1990's (12,000 Sorties/ 19,000 Flying Hours)
  - Organization(s) Involved: USAF
- Key Difference
  - Baseline: Voice Only Communications
  - Treatment: Voice Supplemented with Link 16
- Dependent Variable: Kill Ratio

*Orchestrated and Analyzed by Joint Tactical Information Distribution System (JTIDS) Operational Special Project

Air-to-Air Combat: 4 vs. 4 Engagement



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The Bottom Line Result

- Sharing of Information Across Platforms Involved in Operation Resulted in a Kill Ratio Improvement of Greater Than 2 to 1 (2.61 x Increase- Day; 2.59 x Increase- Night)

Kill Ratio

	Voice Only	Voice + Link 16
Day	3.10	8.11
Night	3.62	9.40

  - Under the Following Conditions:
    - Blue Mission Capability Packages (MCPs) were Co-evolved
    - No Red Learning

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Problem Formulation

- Identify the Research Question
- Identify the Relevant Variables
- Identify the Assumptions and Constraints

Identify the Research Question

Identify the Research Question:

What Explains the Difference in Kill Ratios Between Fighter Planes Equipped with Voice Only and Those Equipped with Link 16 Data Communication Capabilities?

Identify the Relevant Variables (1)

- Dependent Variable: Degree of Effectiveness (Increased Kill Ratios)
- Independent Variable: Co-Evolved Mission Capability Package (MCP) that Results from the Introduction of Link 16 Data Communication Capability
  - MCP Elements Include:
    - CONOPS/Doctrine
    - Organization
    - Command Arrangements
    - Training/Education
    - Personnel
    - Others …
- Treatment: Introduction of Link 16 Data Communication Capability

Identify the Relevant Variables (2)

- Other Independent Variables
  - Controllable: They Can be Manipulated (Physical and Information Domains)
    - Quality of Organic Information
    - Quality of Networking
    - Degree of Information "Share-ability"
  - Uncontrollable: It is Possible to Alter them but they Depend on Human Decisions (Social and Cognitive Domains)
    - Quality of Individual Information
    - Degree of Shared Information
    - Degree of Shared Sensemaking
    - Degree of Actions/ Entities Synchronized

Identify the Assumptions and Constraints

- Assumptions:
  - No Red Learning
- Constraints on Variables: "Acceptable" Thresholds or Limits on the Variables
  - Red Behavior Did Not Vary
- Study Limitations:
  - Data Available Only for a Limited Number of Variables: Number of Sorties, Kill Ratios for Missions with Voice Only and Voice + Link 16 Across Day and Night Operations
    - No Data on Many Conceptual Framework Variables
    - Limited "Test" of the Conceptual Framework
  - Findings May be Limited to Tactical Combat

Agenda

- Case Study Background
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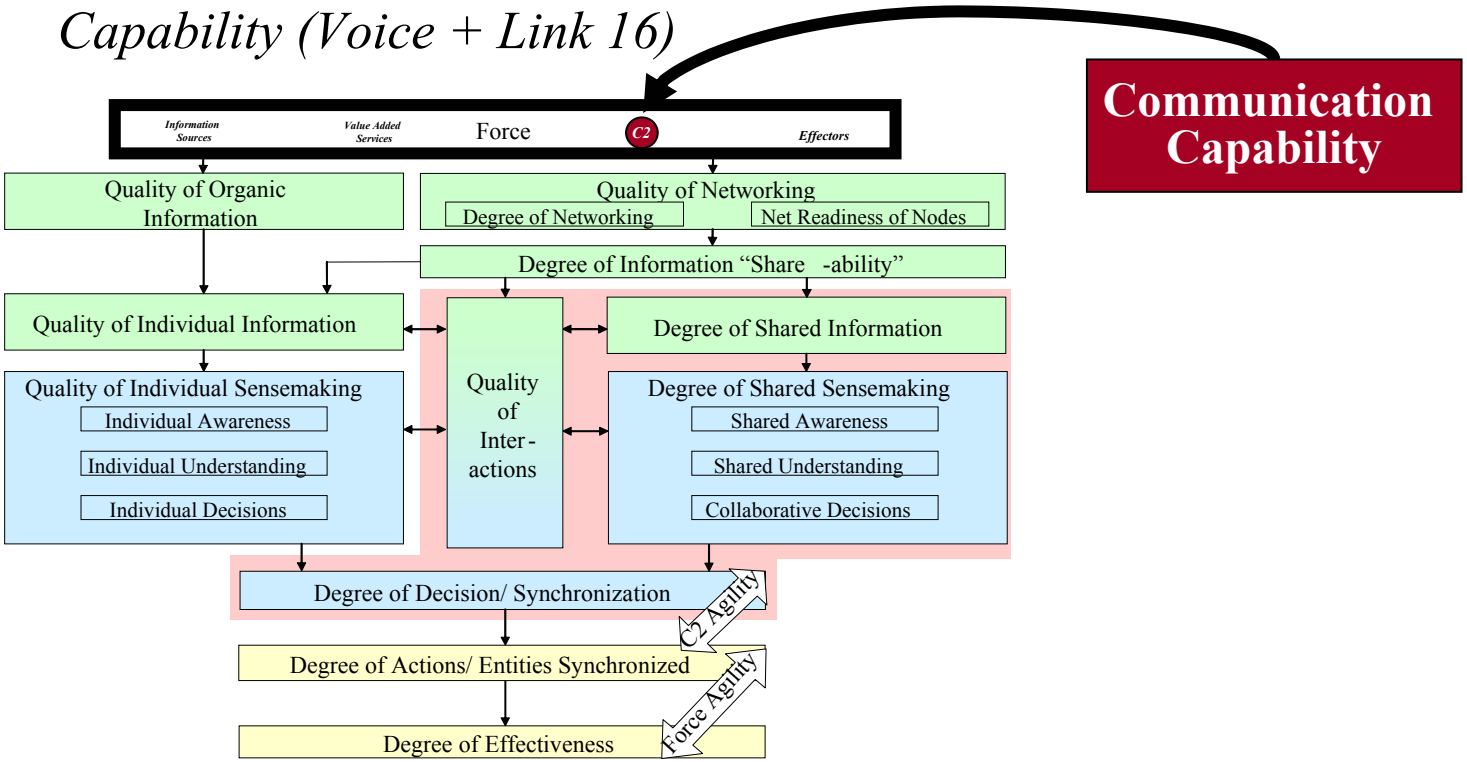
Solution Strategy

- Postulate a "Conceptual Model" (NCO "Story Line")
- Identify What We Know
- Identify What We Need to Know

The Story Line (As it Unfolds)

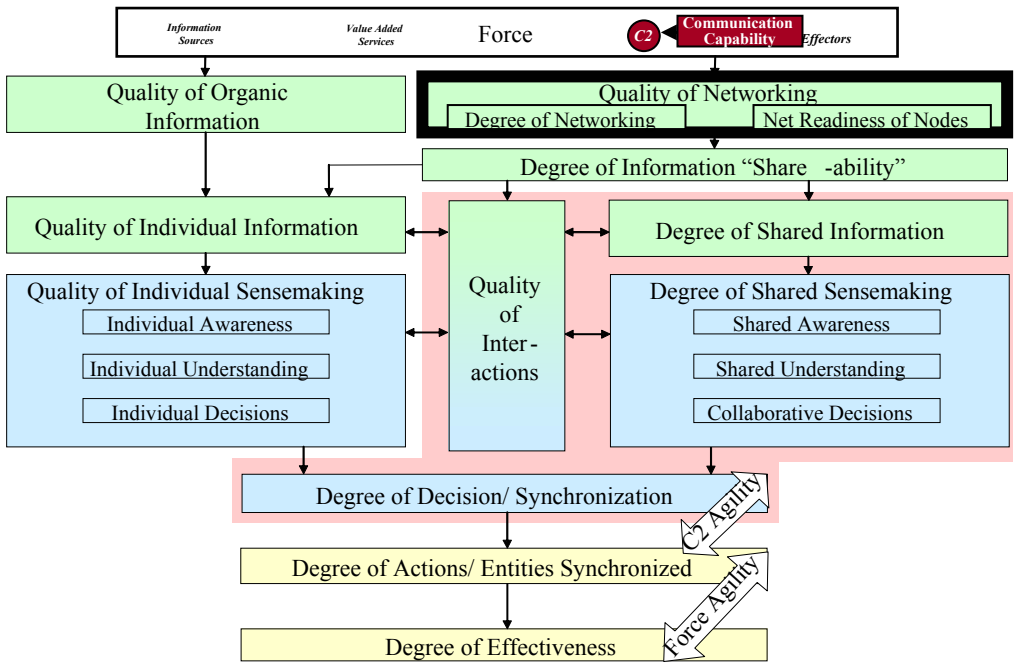
Change in Communications Capability (Voice + Link 16)



The Story Line (As it Unfolds)

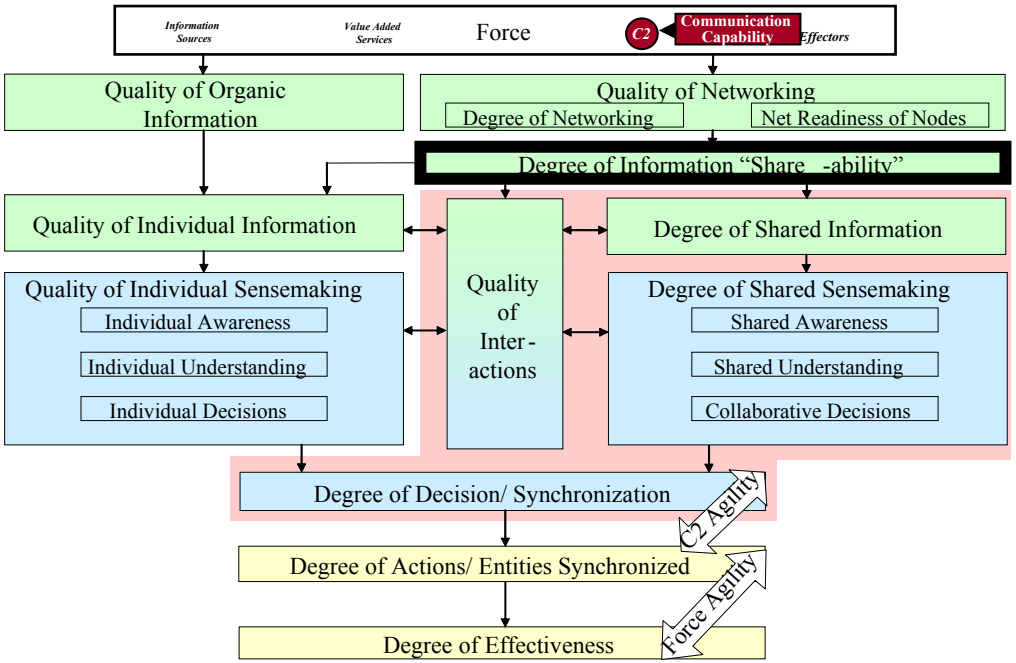
Change in Communications Capability (Voice + Link 16)

Results in improvements in the Quality of the Network, and…



The Story Line (As it Unfolds)

Change in Communications Capability (Voice + Link 16) → *Results in improvements in the Quality of the Network, and …* → *Improvements in Information Share-ability*



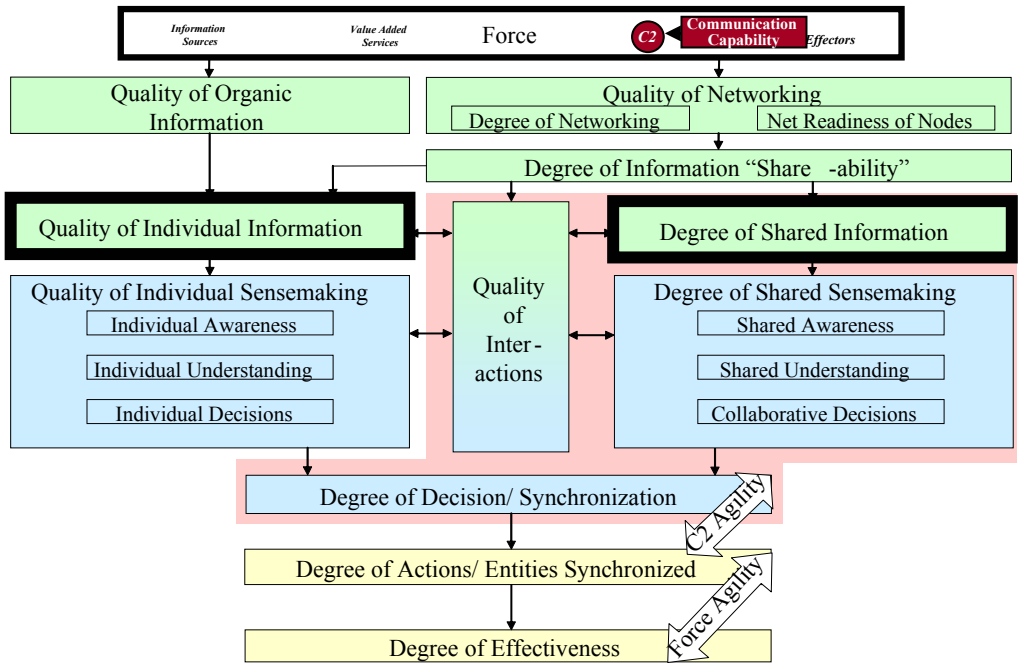
The Story Line (As it Unfolds)

Change in Communications Capability (Voice + Link 16)

Results in improvements in the Quality of the Network, and ...

Improvements in Information Share-ability

That lead to better quality information obtained and shared by individuals and teams



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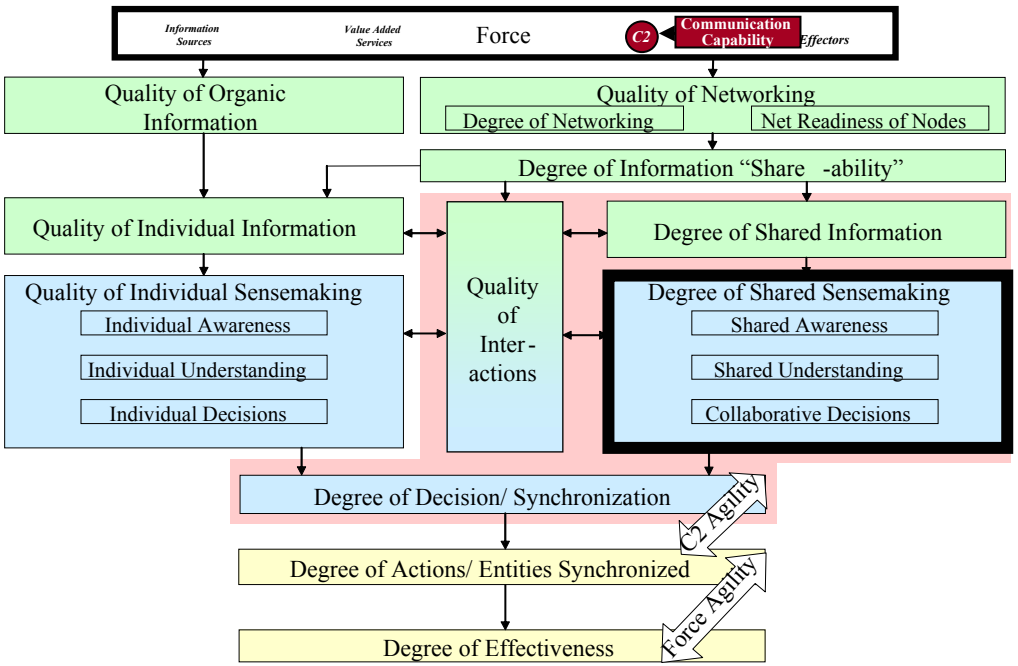

Improvements in Information Share-ability

That lead to better quality information obtained and shared by individuals and teams

That lead to improved Shared Sensemaking

The Story Line (As it Unfolds)

Change in Communications Capability (Voice + Link 16)

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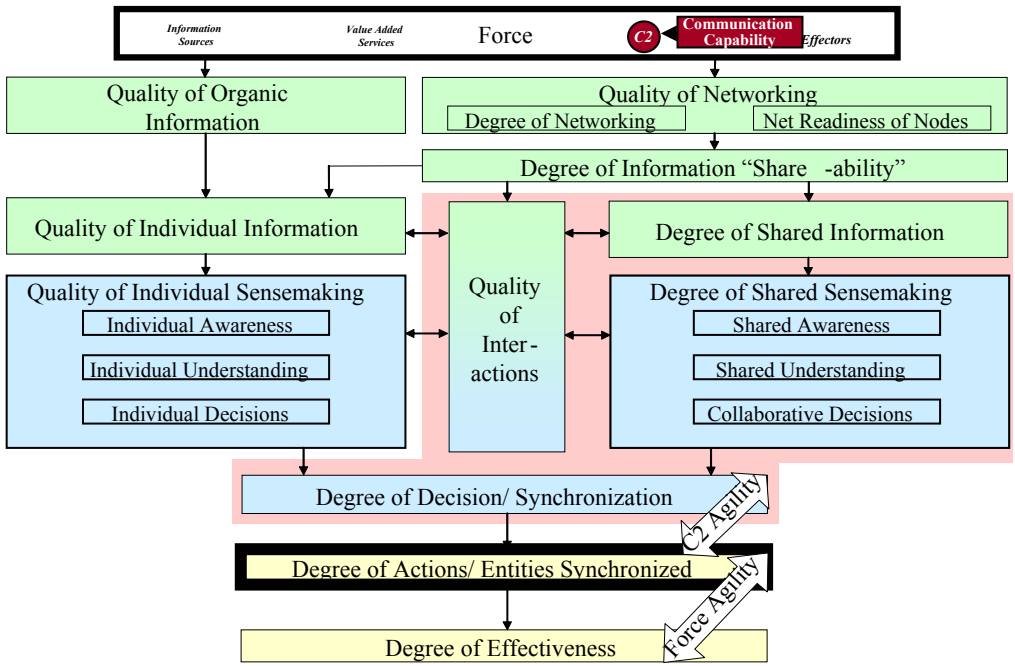


Improvements in Information Share-ability

That lead to better quality information obtained and shared by individuals and teams

That lead to improved Shared Sensemaking

That contributes to enhanced Action/Entity Synchronization

The Story Line (As it Unfolds)

Change in Communications Capability (Voice + Link 16)

Results in improvements in the Quality of the Network, and…

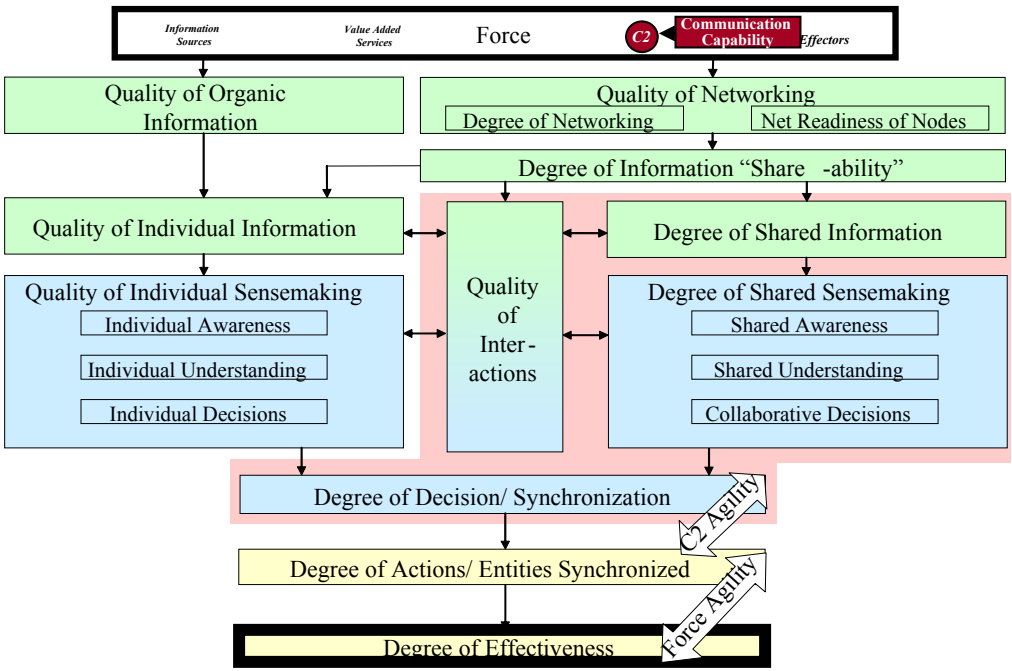
Improvements in Information Share-ability

That lead to better quality information obtained and shared by individuals and teams

That lead to improved Shared Sensemaking

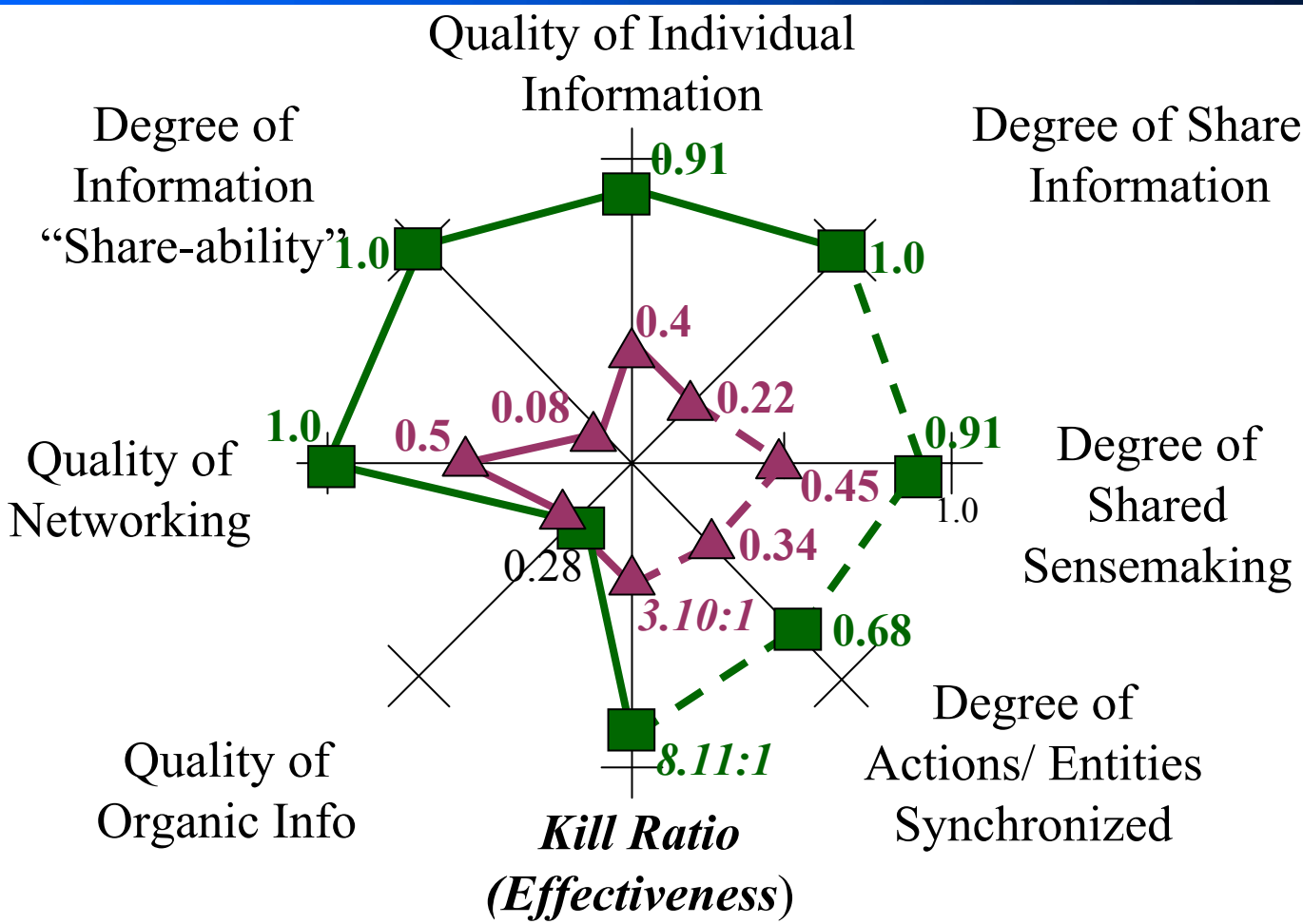
That contributes to enhanced Action/Entity Synchronization

That ultimately results in dramatically improved Effectiveness



NCO Value Chain

Degree of Effectiveness



Overall average over information quality dimensions and package members

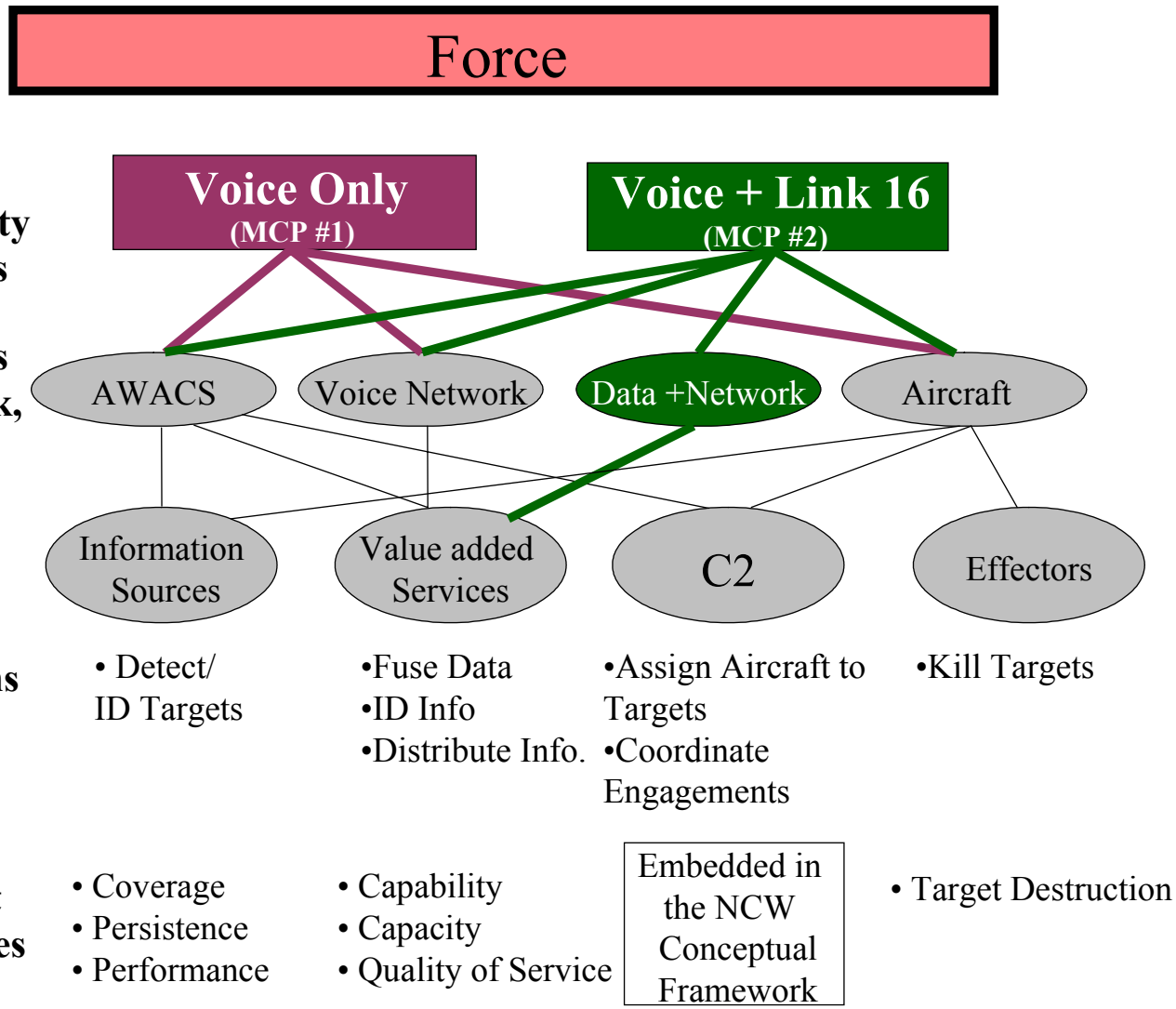
Solution Strategy

- Postulate a "Conceptual Model" (NCO "Story Line")
- Identify What We Know
- Identify What We Need to Know

Identify What We Know

- Mission Capability Package (MCP) that Represents the Baseline (with Voice Only Comms) and MCP that Represents the Co-Evolved Impact of the Treatment (with Voice + Link 16 Comms)
- The Differences in Quality of Organic Information, Quality of Networking, Degree of Information Share-ability, Quality of Individual Information, and Degree of Shared Information Resulting from Voice + Link 16
- Hypothesized Differences in Degree of Shared Sensemaking and Degree of Actions/ Entities Synchronized

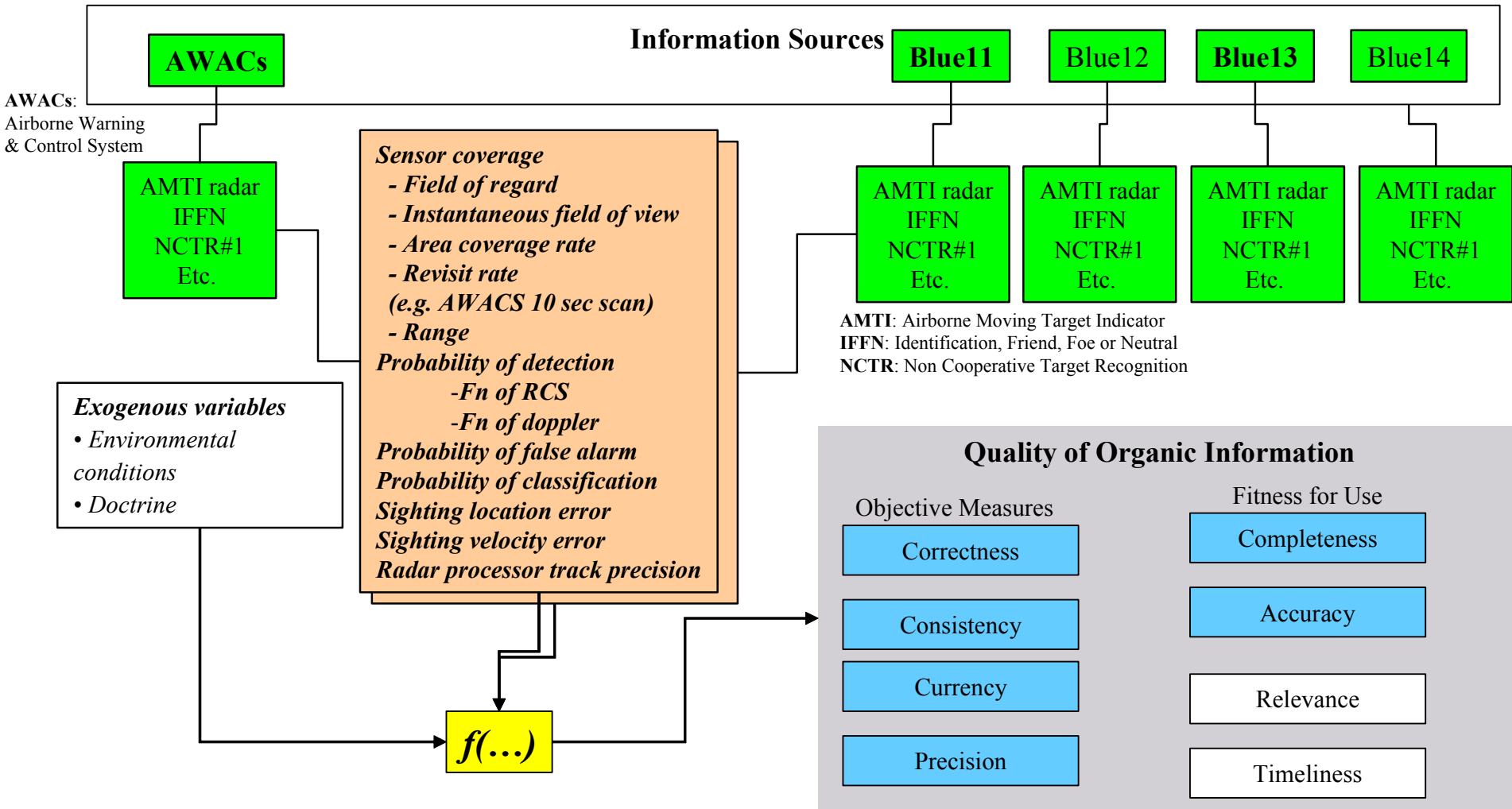
MCP: Base Line vs. Treatment



Explanation of Numeric Values for NCO CF Variables

- The Numeric Values for the NCO CF Variables Were Computed by the RAND Case Study Team Using an Analytica Model
- Model Functions Based on Quantitative and Qualitative Inputs
  - Quantitative Inputs:
    - Known Performance of Voice and Link 16 Communication Systems
    - Known Performance of Other Related Hardware (Sensors, etc.)
    - Known Exogenous Factors (Training, Team Structure, Doctrine, etc.)
  - Qualitative Inputs:
    - Interviews with Pilots and Other SMEs
    - Research and Analysis of Existing Documents

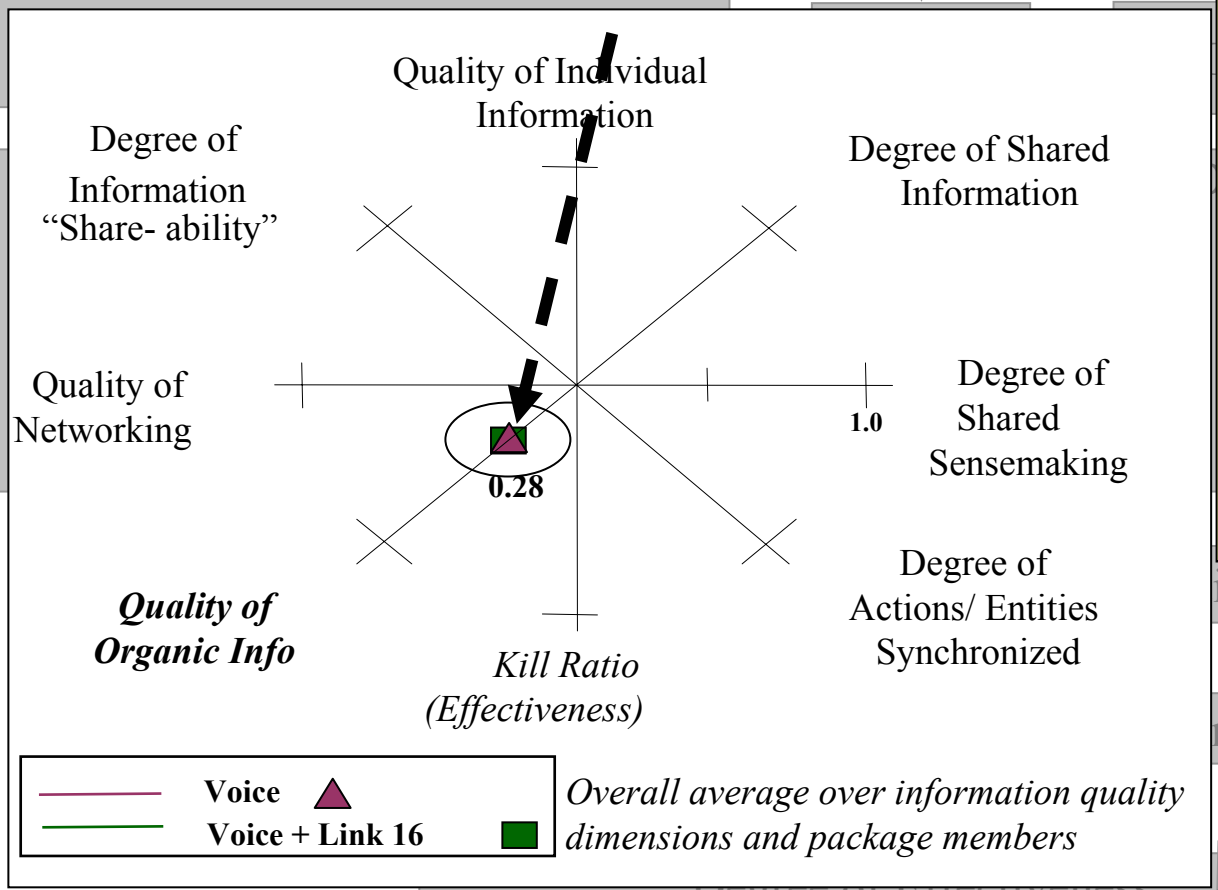
Example Computational Method: Quality of Organic Information



What We Know: Quality of Organic Information

Information Sources | *Value Added Services* | **Force** | C2 ← **Communication Capability**

Quality of Organic Information

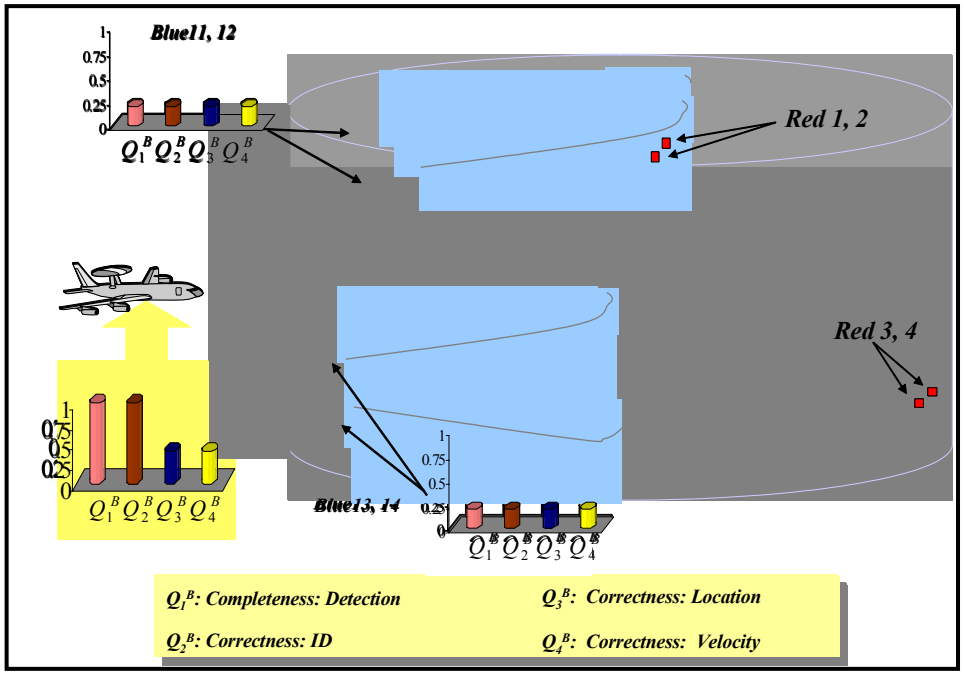


Note: It is assumed that the Quality of Organic Information is the same for operations with Voice Only and Voice + Link 16 (i.e., communication capability has no effect on Quality of Organic Information)

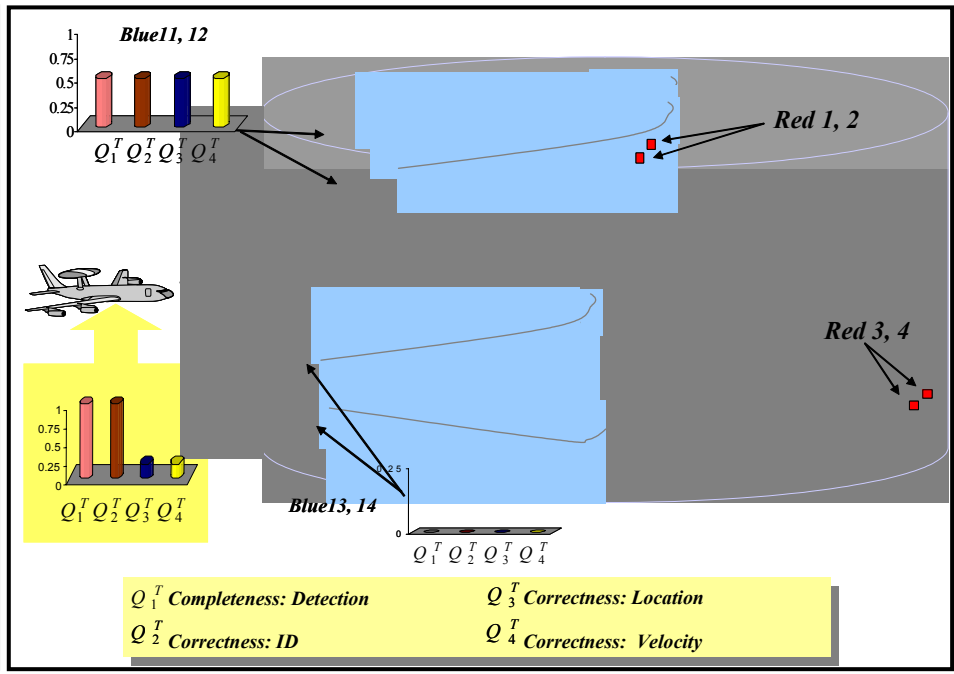
Quality of Organic Information Provides the foundation for the Quality of Information Calculations

Explanation of Quality of Organic Information Values

What Blue Knows About Blue



What Blue Knows About Red



Note: It is assumed that the Quality of Organic Information is the same for operations with Voice Only and Voice + Link 16 (i.e., communication capability has no effect on Quality of Organic Information)

Quality of Organic Information = 0.28 (Based on completeness and correctness of known sensor performance; see slide 27 for details on computation method)

Quality of Organic Information

Information Gathered by Individual Sensors that is Not Shared and is Unavailable to the Network

The Quality of Organic Information is the Same for Operations with Voice Only and with Voice + Link 16

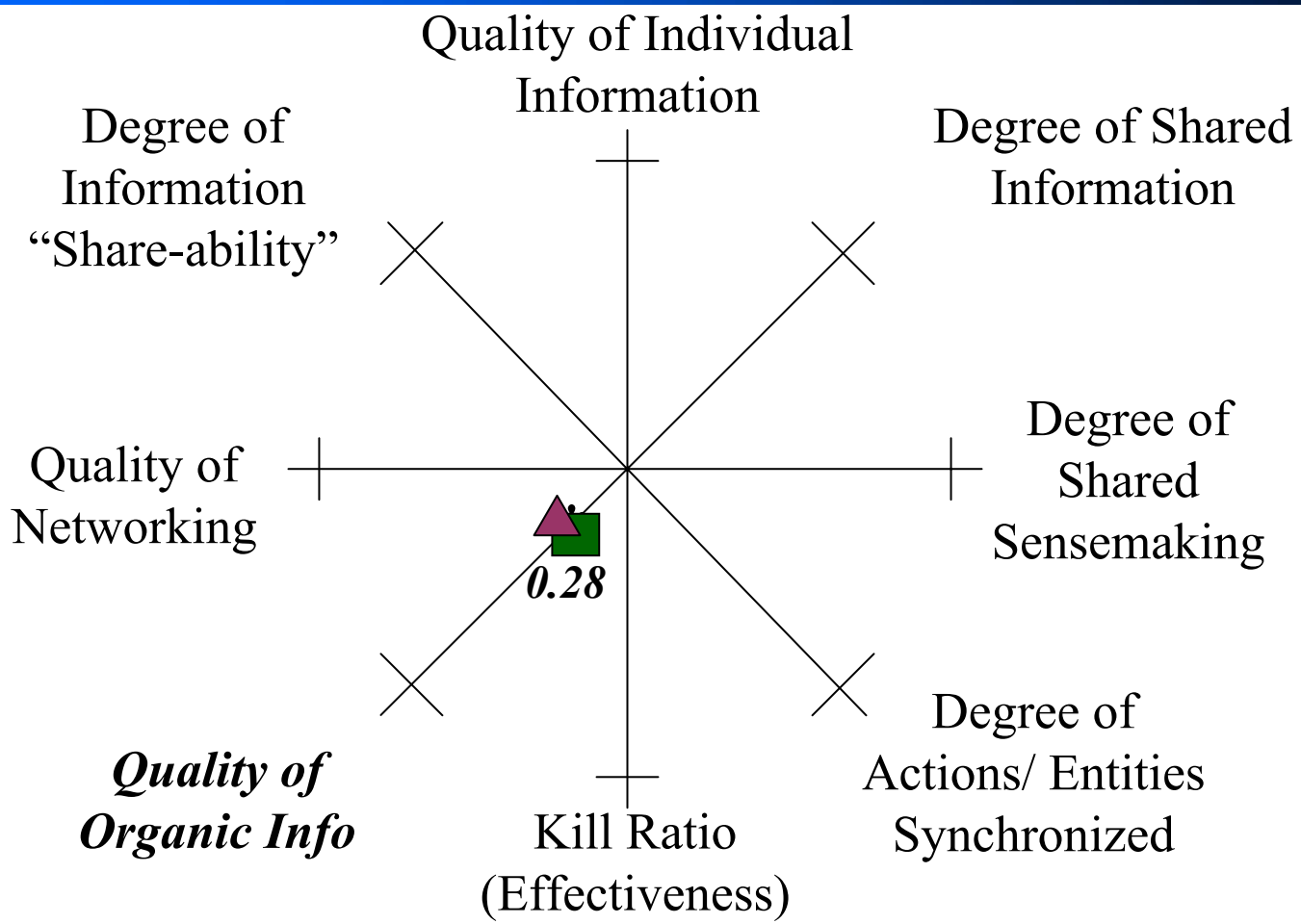
Attribute	Voice Only (.28)	Link 16 (.28)
Correctness	No Difference	No Difference
Consistency	No Difference	No Difference
Currency	No Difference	No Difference
Precision	No Difference	No Difference
Completeness	No Difference	No Difference
Accuracy	No Difference	No Difference
Relevance	No Difference	No Difference
Timeliness	No Difference	No Difference

Value of NCO CF Variable

Value of NCO CF Attribute

Note: The Values of the NCO CF Variables were Calculated Using an Analytica Model. The Nominal Values for Each Attribute Are Estimates that Reflect the Calculations Performed in the Model.

Quality of Organic Information



Voice
Voice + Link 16

Overall average over information quality dimensions and package members

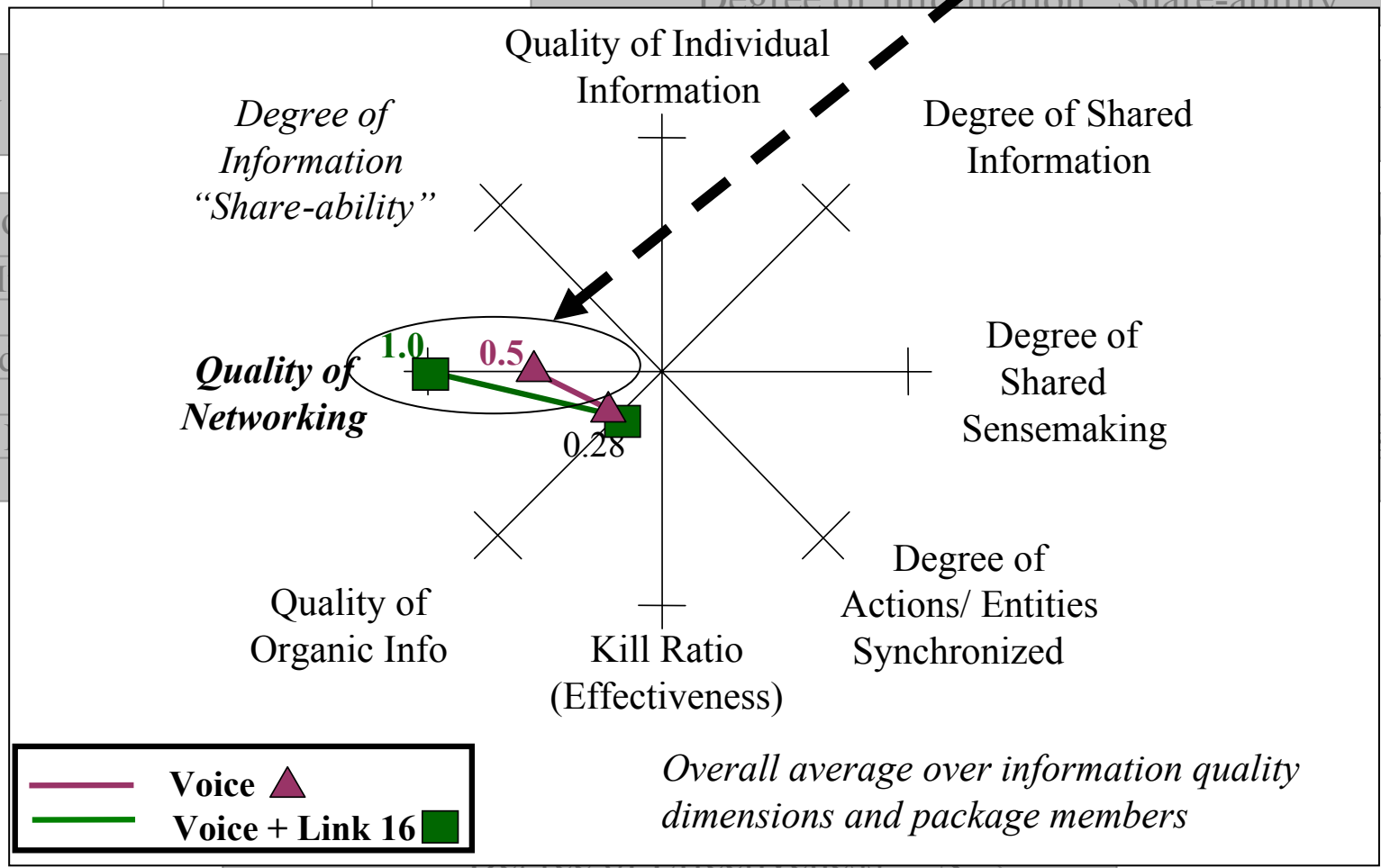
What We Know: Quality of Networking

Information Sources | *Value Added Services* | Force | C2 | **Communication Capability**

Quality of Organic Information

Quality of Networking

Degree of Networking | **Net Readiness of Nodes**



Explanation of Quality of Networking Values

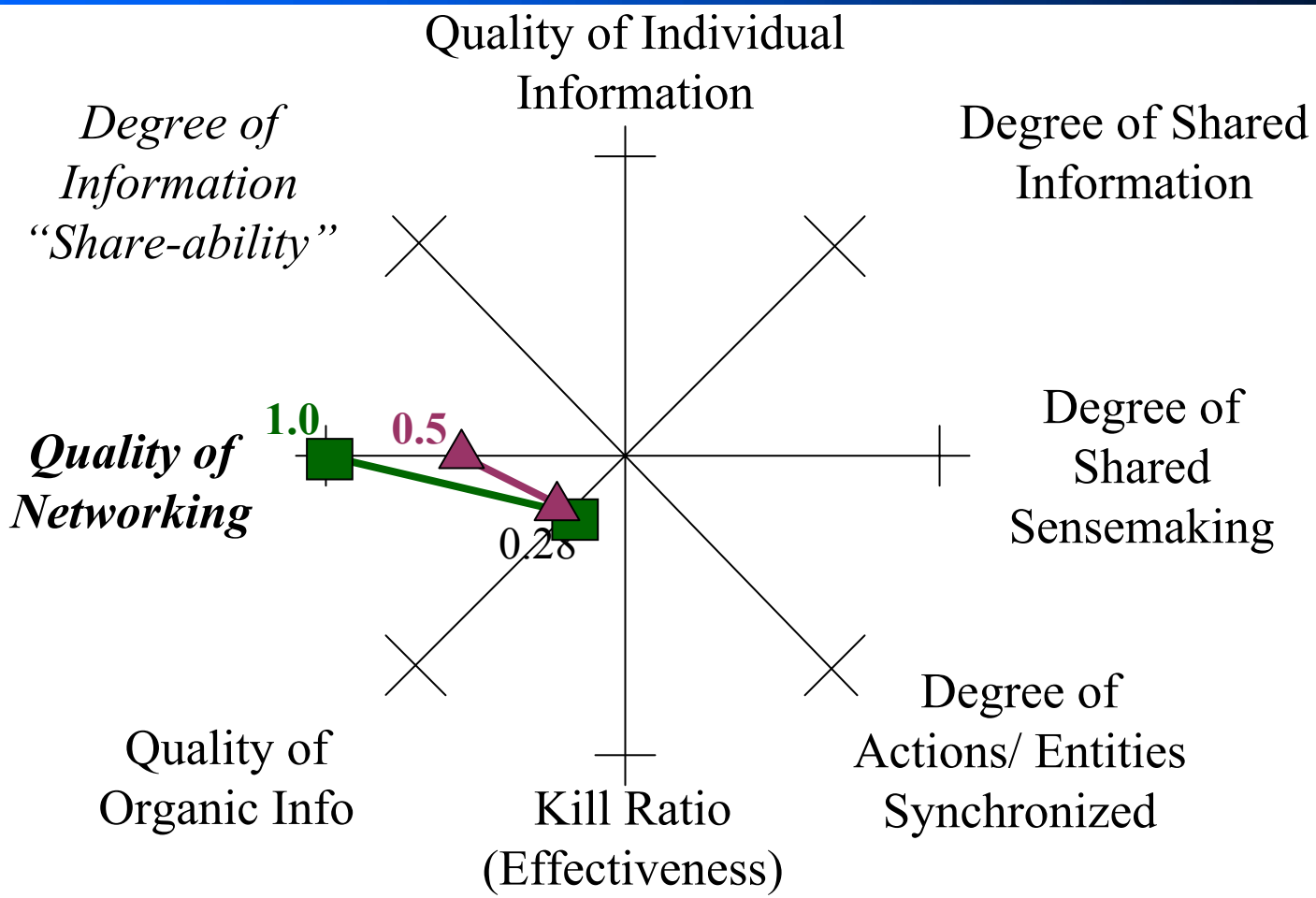
- Based on Quality of Service Metrics, There was a Two-fold Improvement in Network Quality Between the Baseline and Treatment
- Calculations Based on Known Performance Standards of Voice and Link 16 Communication Systems (See Next Slide for Details)

Quality of Networking

Attribute	Voice Only (0.5)	Link-16 (1.0)
Degree of Networking		
Reach	AWACS over Radio	AWACS over Link 16
Quality of Service	One Military Vocoder Channel (Limited Capacity)	Link 16 (Capacity Exceeds Need)
Network Assurance	Assumed 100%	Assumed 100%
Network Agility	Assumed Static	Assumed Static
Net Readiness of Nodes		
Capacity	Not Calculated	Not Calculated
Connectivity	Not Calculated	Not Calculated
P & R Capability Support	Not Calculated	Not Calculated
Collaboration Support	Not Calculated	Not Calculated
Node Assurance	Not Calculated	Not Calculated

Note: The Values of the NCO CF Variables were Calculated Using an Analytica Model. The Nominal Values for Each Attribute Are Estimates that Reflect the Calculations Performed in the Model.

Quality of Networking



Overall average over information quality dimensions and package members

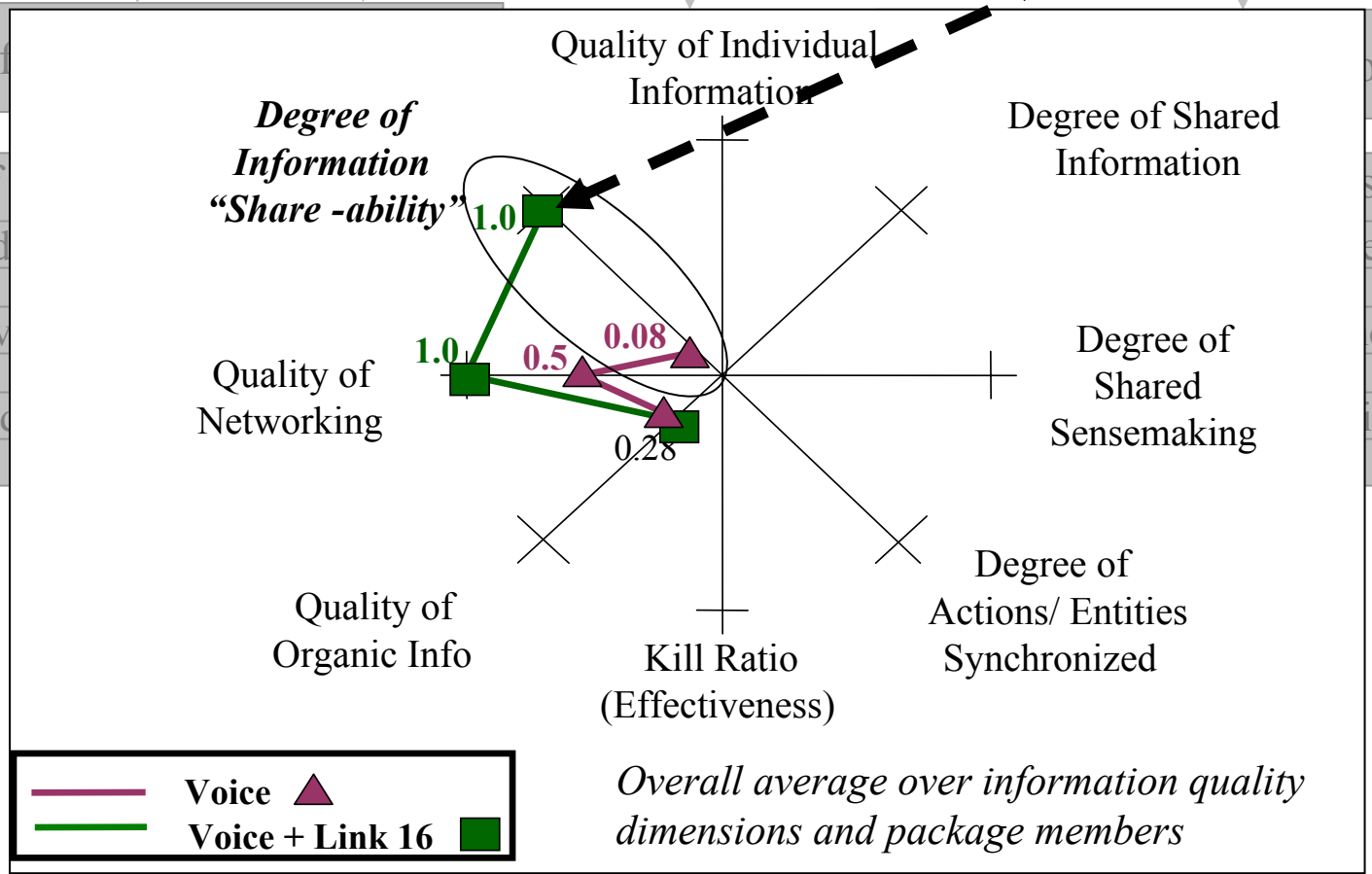
What We Know: Degree of Information "Share-ability"

Information Sources | *Value Added Services* | Force | C2 | **Communication Capability**

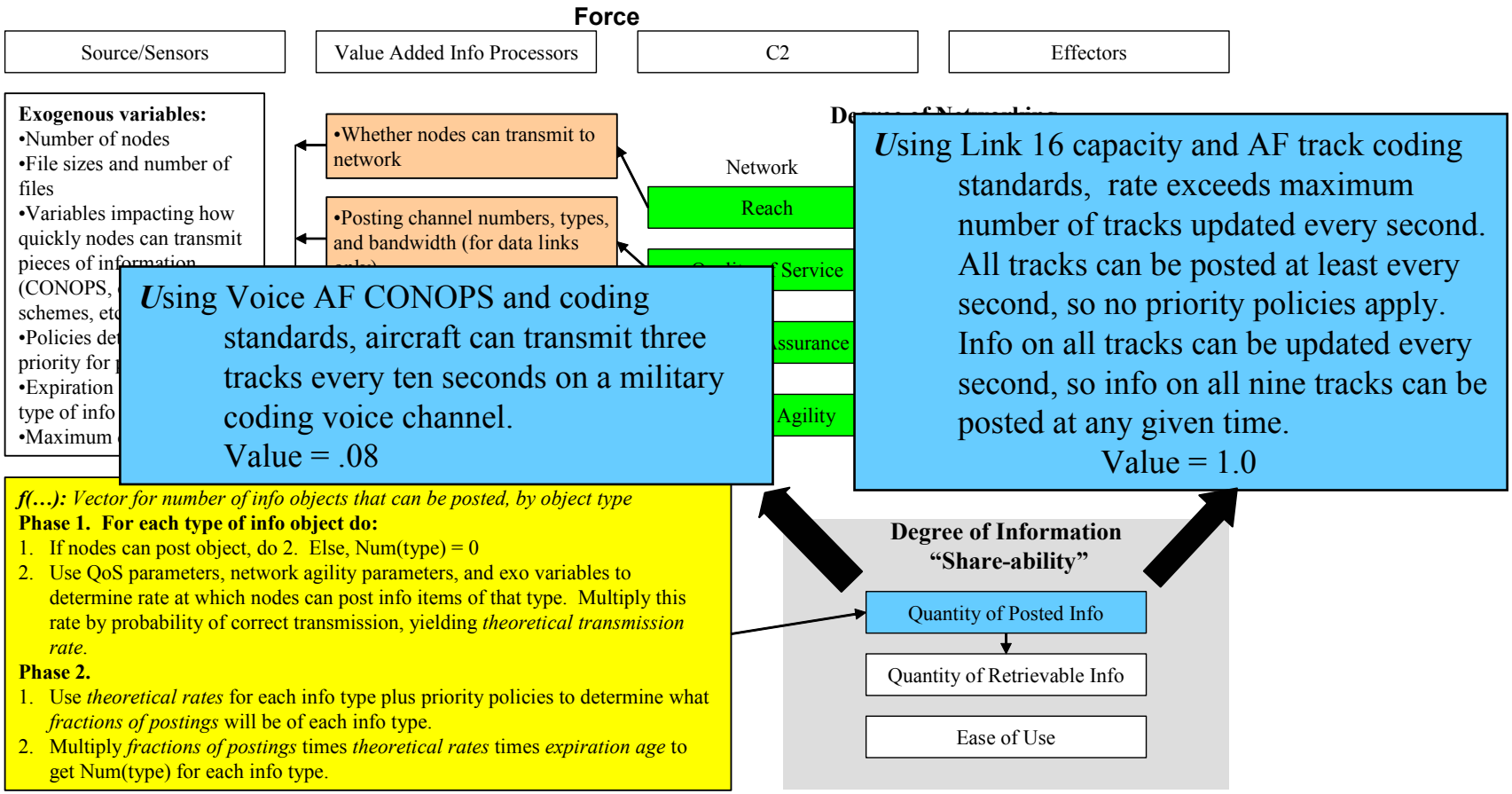
Quality of Organic Information

Quality of Networking
- Degree of Networking
- Net Readiness of Nodes

Degree of Information "Share-ability"



Explanation of Degree of Information "Share-ability" Values



Note: Calculations based on a single attribute (Quantity of Posted Information). In general, calculations should be based on as many attributes as possible.

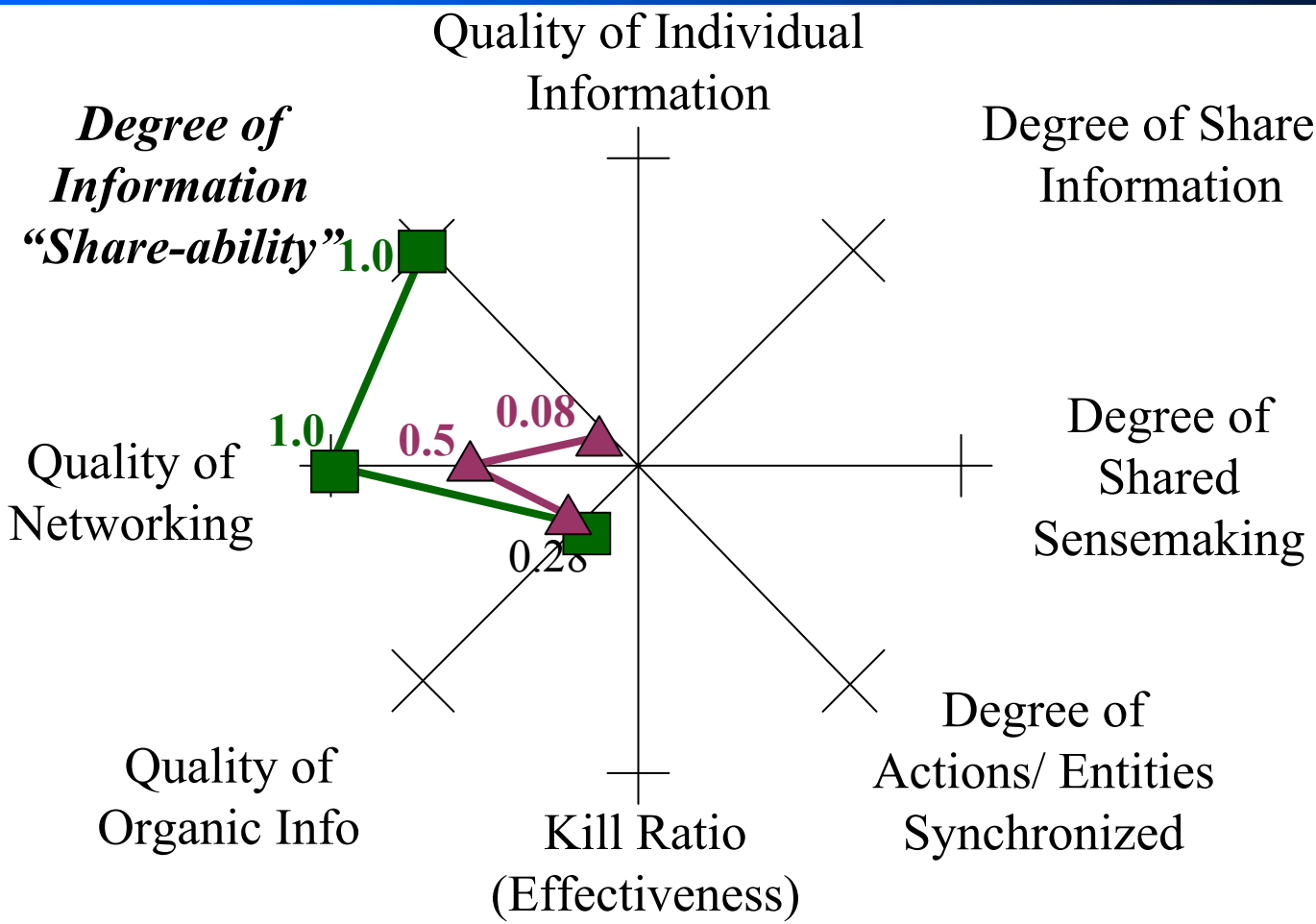
Degree of Information "Share-ability"

The Degree to Which Information Could be Shared Among Force Entities

Attribute	Voice Only (.08)	Link 16 (1.0)
Quantity of Posted Information	Low	High
Quantity of Retrievable Information	Not Calculated	Not Calculated
Ease of Use	Not Calculated	Not Calculated

Note: The Values of the NCO CF Variables were Calculated Using an Analytica Model. The Nominal Values for Each Attribute Are Estimates that Reflect the Calculations Performed in the Model.

Degree of Information "Share-ability"



Overall average over information quality dimensions and package members

What We Know: Quality of Individual Information

Information Sources | *Value Added Services* | Force | C2 | **Communication Capability**

Quality of Organic Information

Quality of Networking
- Degree of Networking
- Net Readiness of Nodes

Degree of Information "Share-ability"

Quality of Individual Information

Degree of Shared Information

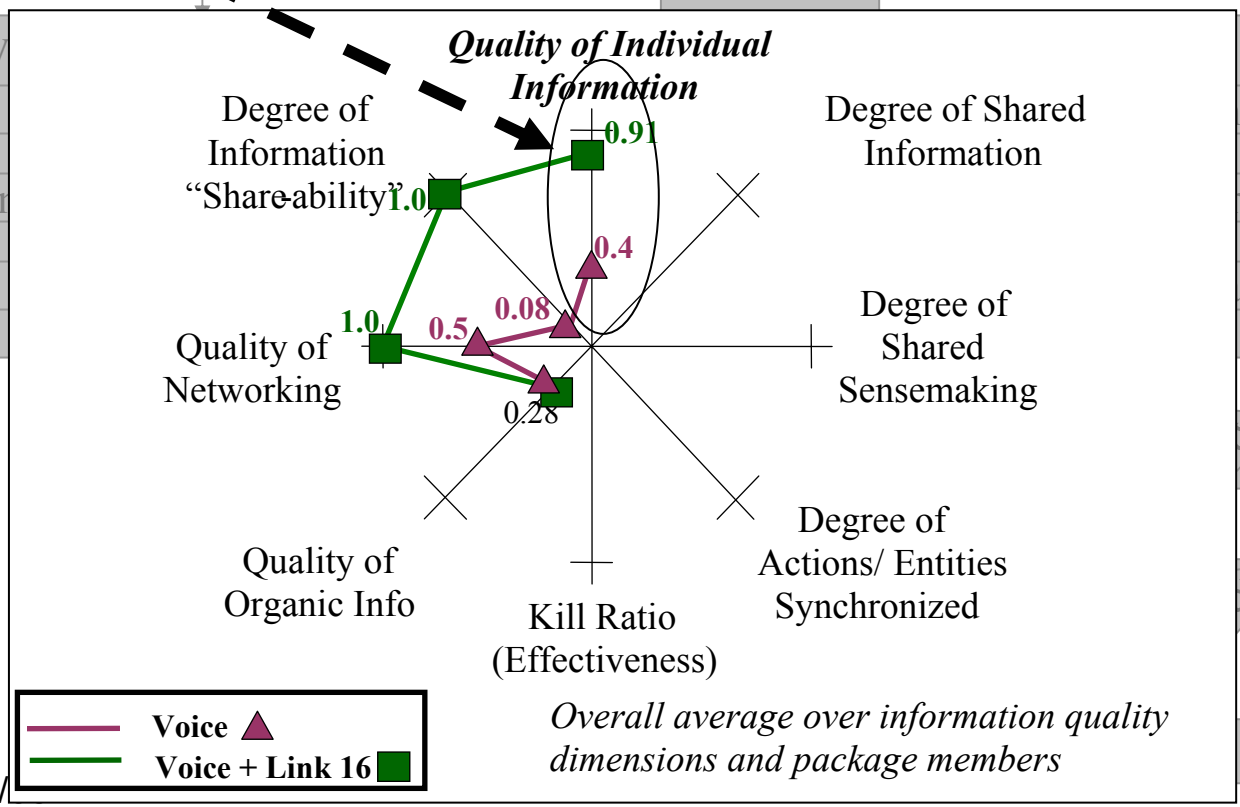
Quality

Shared Sensemaking

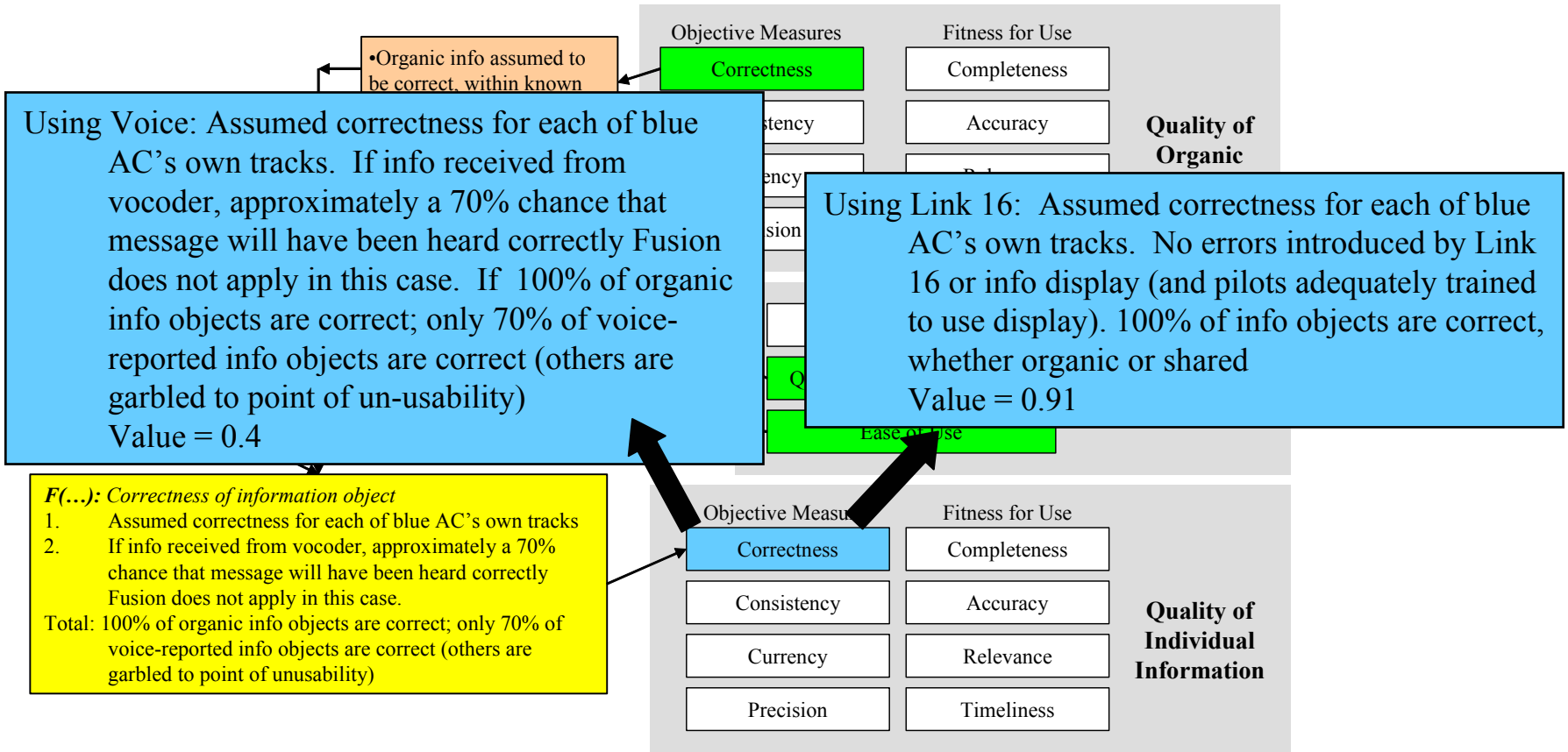
ared Awareness

ed Understanding

borative Decisions



Explanation of Quality of Individual Information Values



Note: Calculations based on a single attribute (Correctness). In general, calculations should be based on as many attributes as possible.

Quality of Individual Information

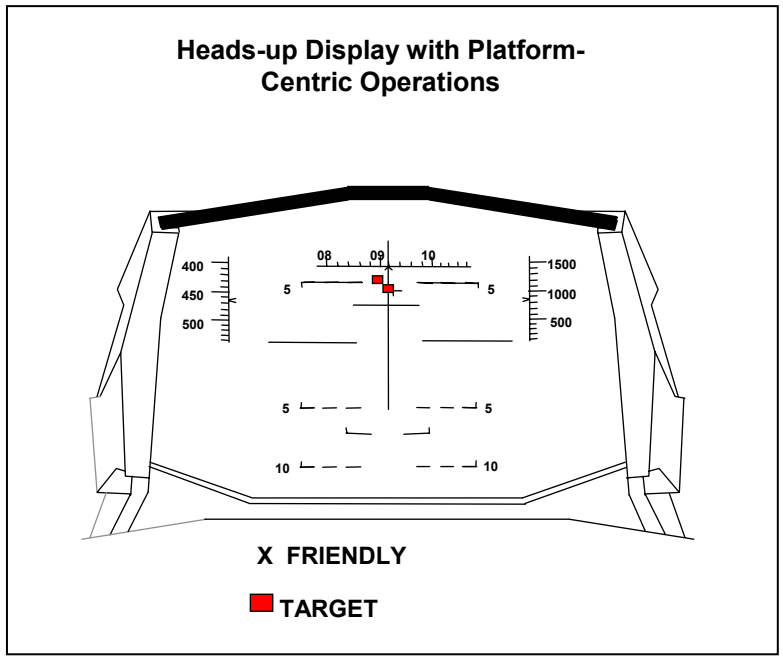
Information Gathered by Individuals from the Network and Organic Sources

Attribute	Voice Only (0.4)	Link 16 (0.91)
Correctness	Medium	High
Consistency	Not Calculated	Not Calculated
Currency	Not Calculated	Not Calculated
Precision	Not Calculated	Not Calculated
Completeness	Not Calculated	Not Calculated
Accuracy	Not Calculated	Not Calculated
Relevance	Not Calculated	Not Calculated
Timeliness	Not Calculated	Not Calculated

Note: The Values of the NCO CF Variables were Calculated Using an Analytica Model. The Nominal Values for Each Attribute Are Estimates that Reflect the Calculations Performed in the Model.

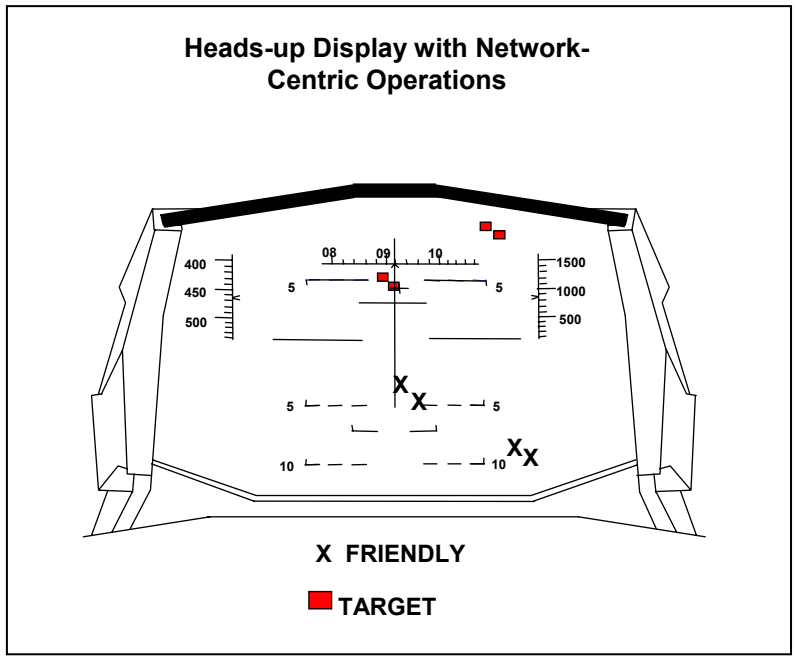
Comparing Quality of Individual Information (1): Baseline vs. Treatment

Voice Only Heads-up Display



Blue Pilot 11 or 12 View
Blue Pilots 13 and 14 See Nothing

Link 16 Heads-up Display

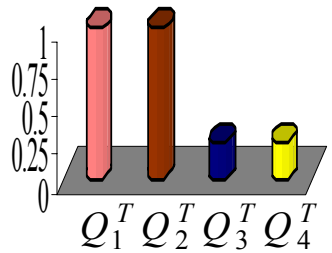


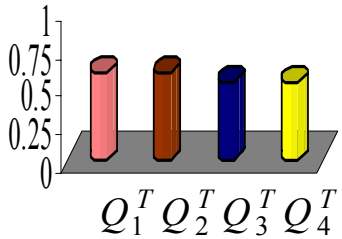
Common Pilot View

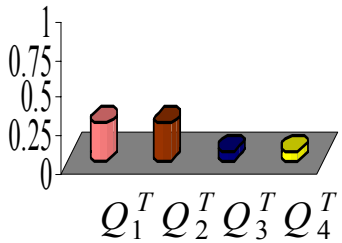
Comparing Quality of Individual Information (2): Baseline vs. Treatment

Voice Only

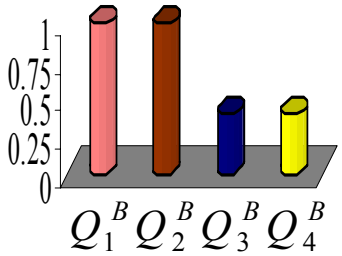
Threat Tracks

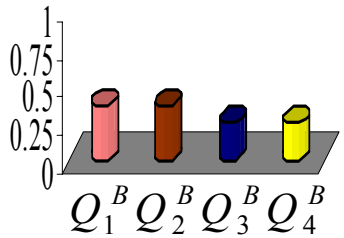


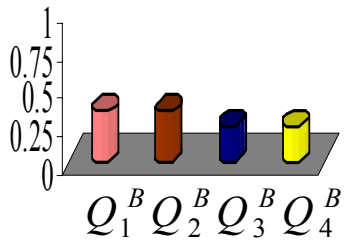




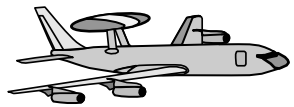
Blue Tracks







AWACS

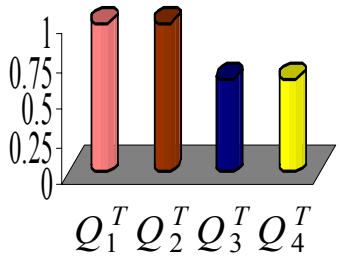


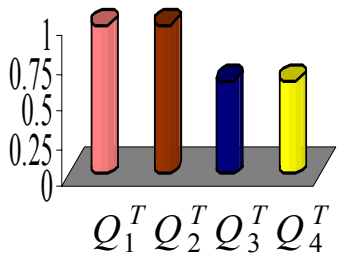
Blue 11 & 12

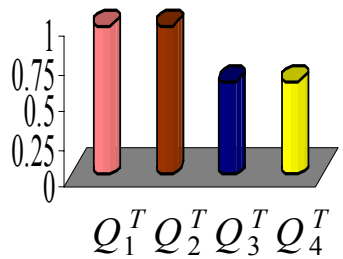
Blue 13 & 14

Link 16 + Voice

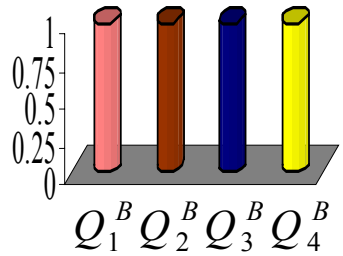
Threat Tracks

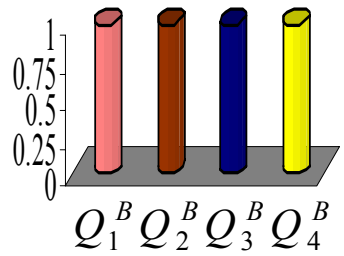


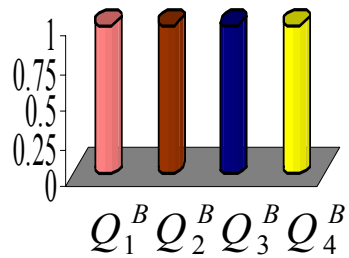




Blue Tracks







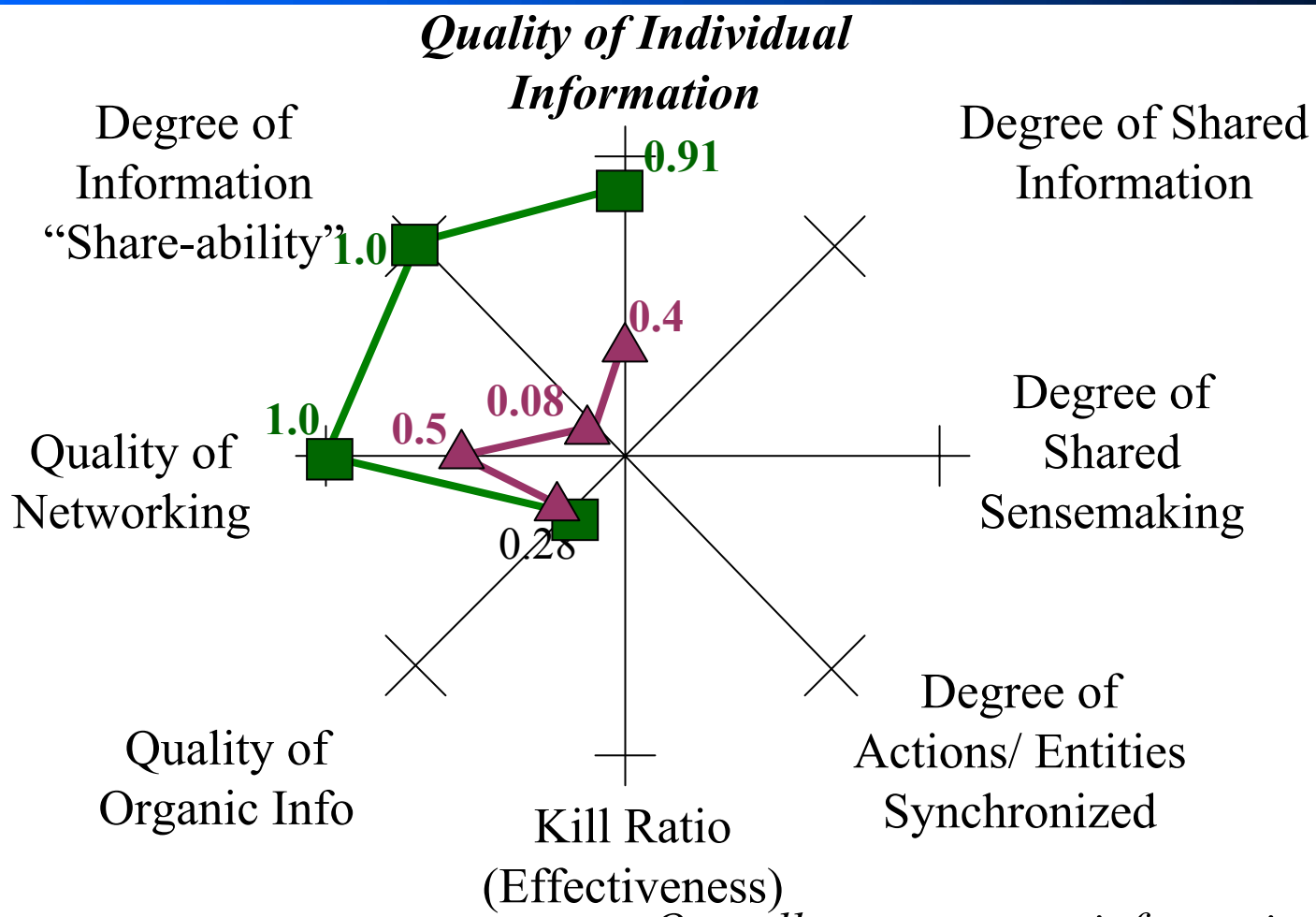
Q_1 ***Completeness: Detection***

Q_2 ***Correctness: ID***

Q_3 ***Correctness: Location***

Q_4 ***Correctness: Velocity***

Quality of Individual Information



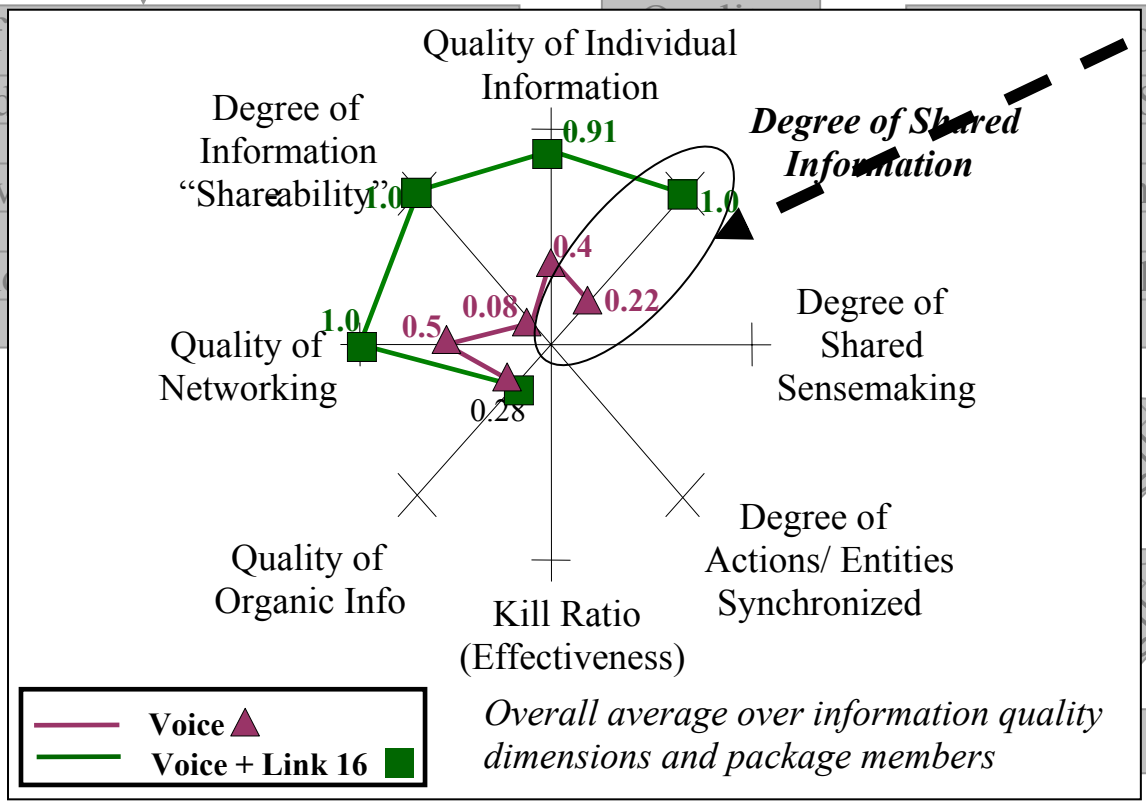
Overall average over information quality dimensions and package members

OFT
OASD/ NII

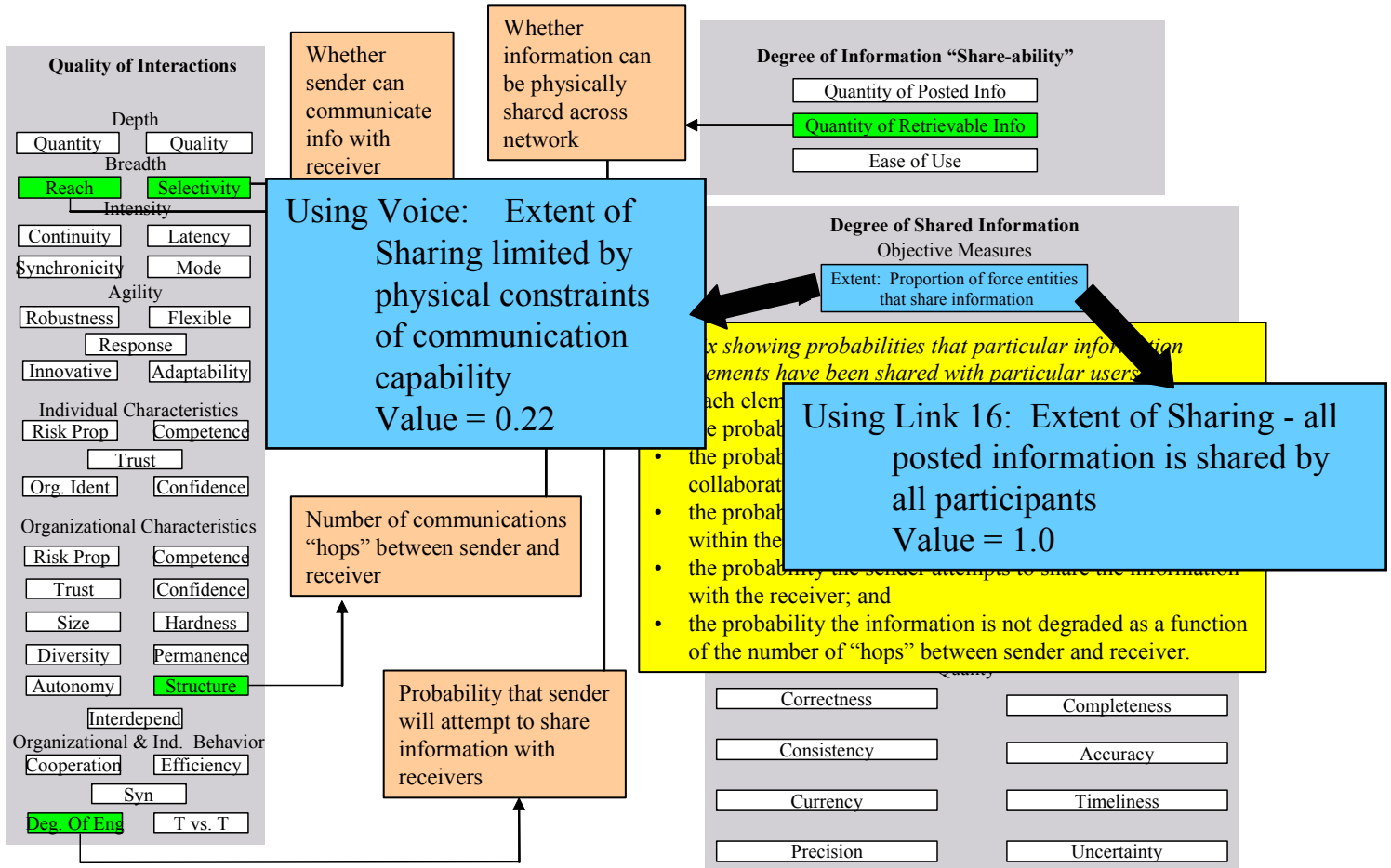
What We Know: Degree of Shared Information

Information Sources | *Value Added Services* | Force | C2 | **Communication Capability**

- Quality of Organic Information
- Quality of Networking
  - Degree of Networking
  - Net Readiness of Nodes
- Degree of Information "Share-ability"
- Quality of Individual Information
- **Degree of Shared Information**



Explanation of Degree of Shared Information Values



Note: Calculations based on a single attribute (Extent). In general, calculations should be based on as many attributes as possible.

Degree of Shared Information

Attribute	Voice Only (0.22)	Link 16 (1.0)
Extent	Low	High
Correctness	Not Calculated	Not Calculated
Consistency	Not Calculated	Not Calculated
Currency	Not Calculated	Not Calculated
Precision	Not Calculated	Not Calculated
Quality	Not Calculated	Not Calculated
Completeness	Not Calculated	Not Calculated
Accuracy	Not Calculated	Not Calculated
Relevance	Not Calculated	Not Calculated
Timeliness	Not Calculated	Not Calculated

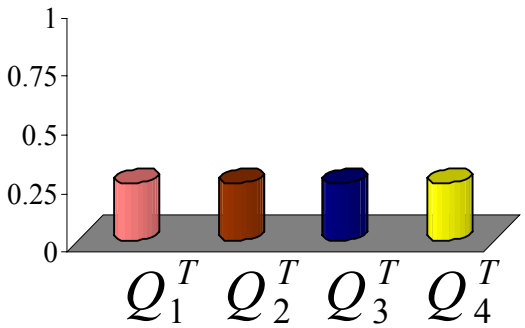
Note: The Values of the NCO CF Variables were Calculated Using an Analytica Model. The Nominal Values for Each Attribute Are Estimates that Reflect the Calculations Performed in the Model.

Comparing Degree of Shared Information (Extent): Base Line vs. Treatment

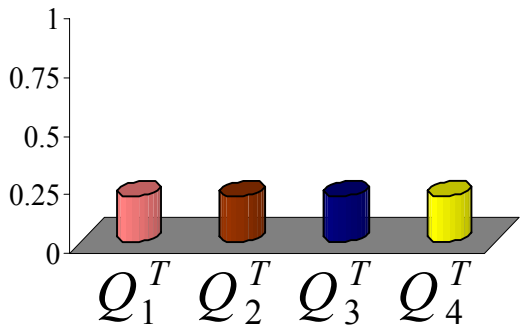
All blue AC have the same shared information in this example (all listen to the same voice channel or receive the same Link 16 broadcasts)

Voice Only

Threat Tracks

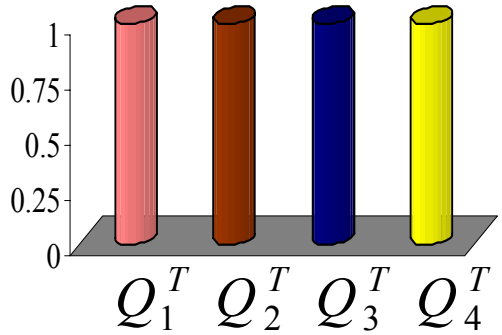


Blue Tracks

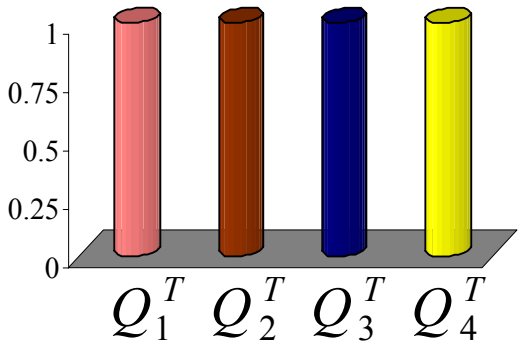


Voice + Link 16

Threat Tracks



Blue Tracks



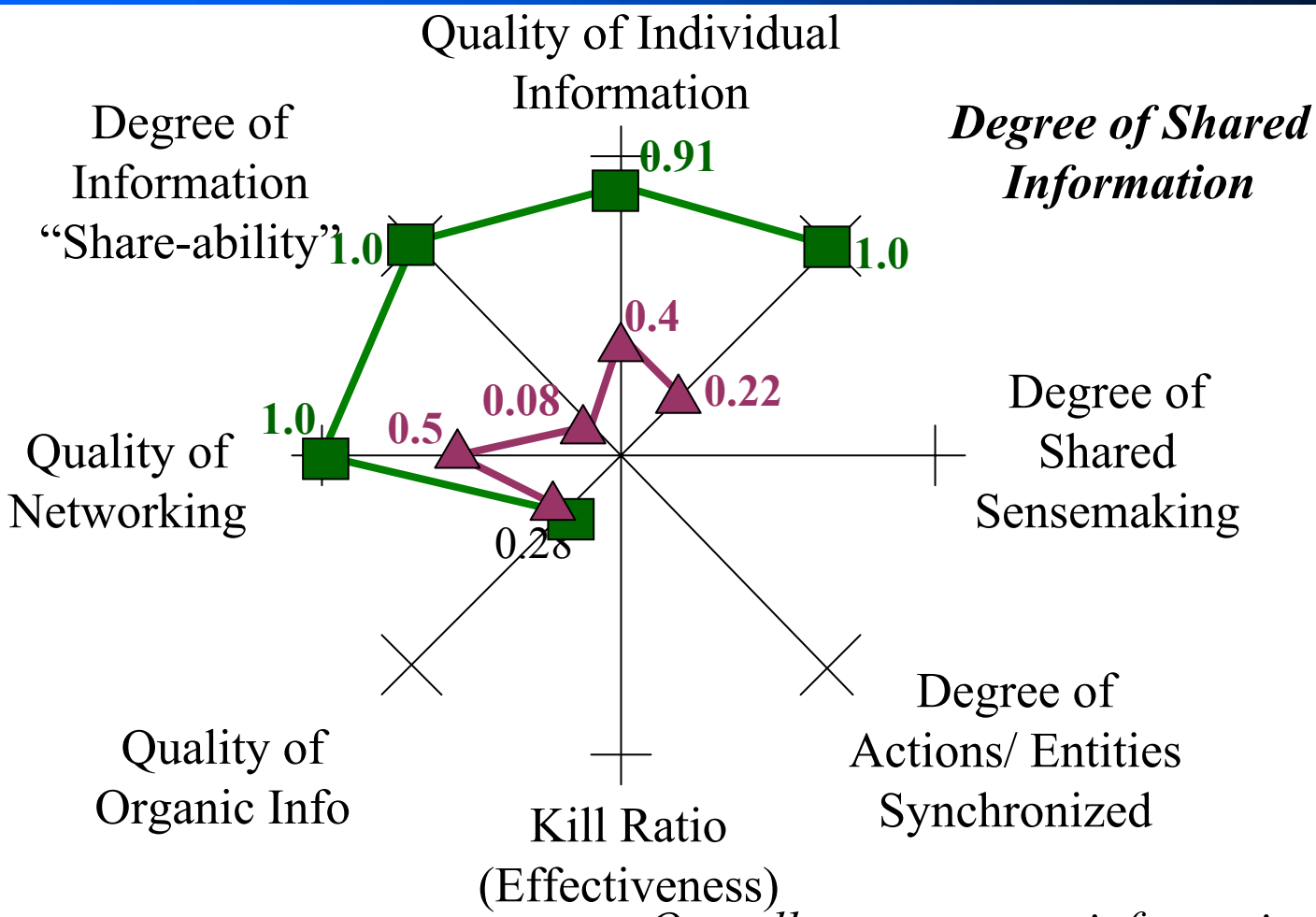
Q_1 ***Completeness: Detection***

Q_2 ***Correctness: ID***

Q_3 ***Correctness: Location***

Q_4 ***Correctness: Velocity***

Degree of Shared Information

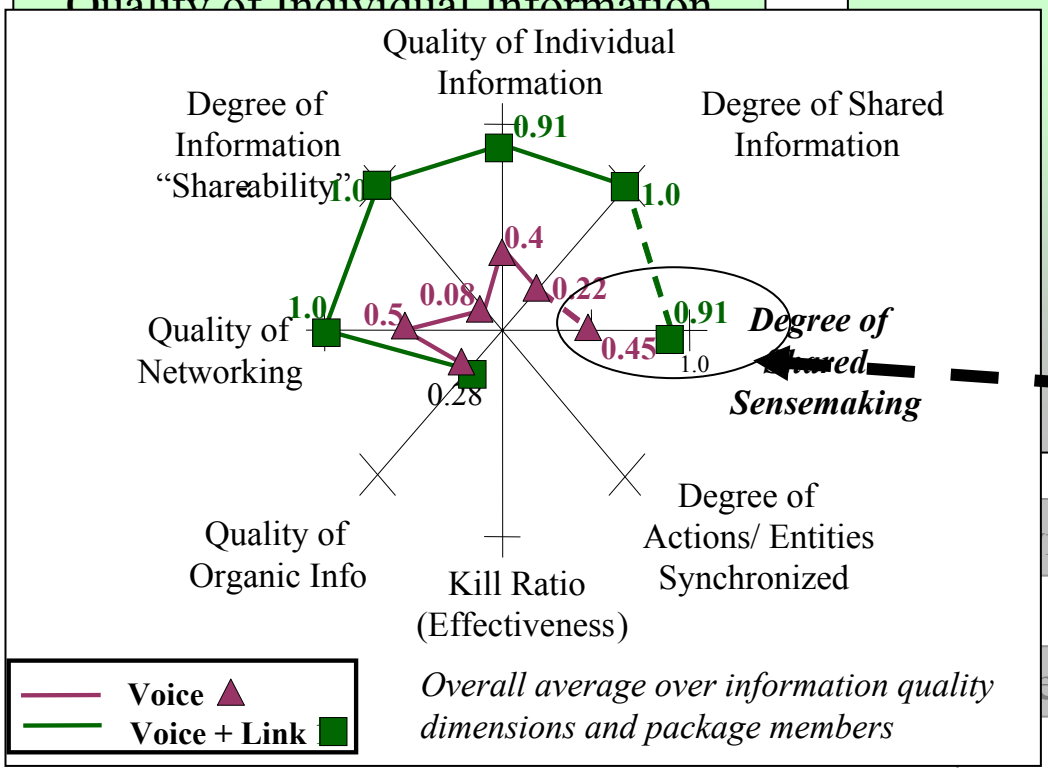


Overall average over information quality dimensions and package members

What We Know (Inferred): Degree of Shared Sensemaking

Information Sources | *Value Added Services* | Force | C2 | **Communication Capability**

- Quality of Organic Information
- Quality of Networking
  - Degree of Networking
  - Net Readiness of Nodes
- Degree of Information "Share-ability"
- Quality of Individual Information
- Degree of Shared Information
- Degree of Shared Sensemaking
  - Shared Awareness
  - Shared Understanding
  - Collaborative Decisions



nchronization

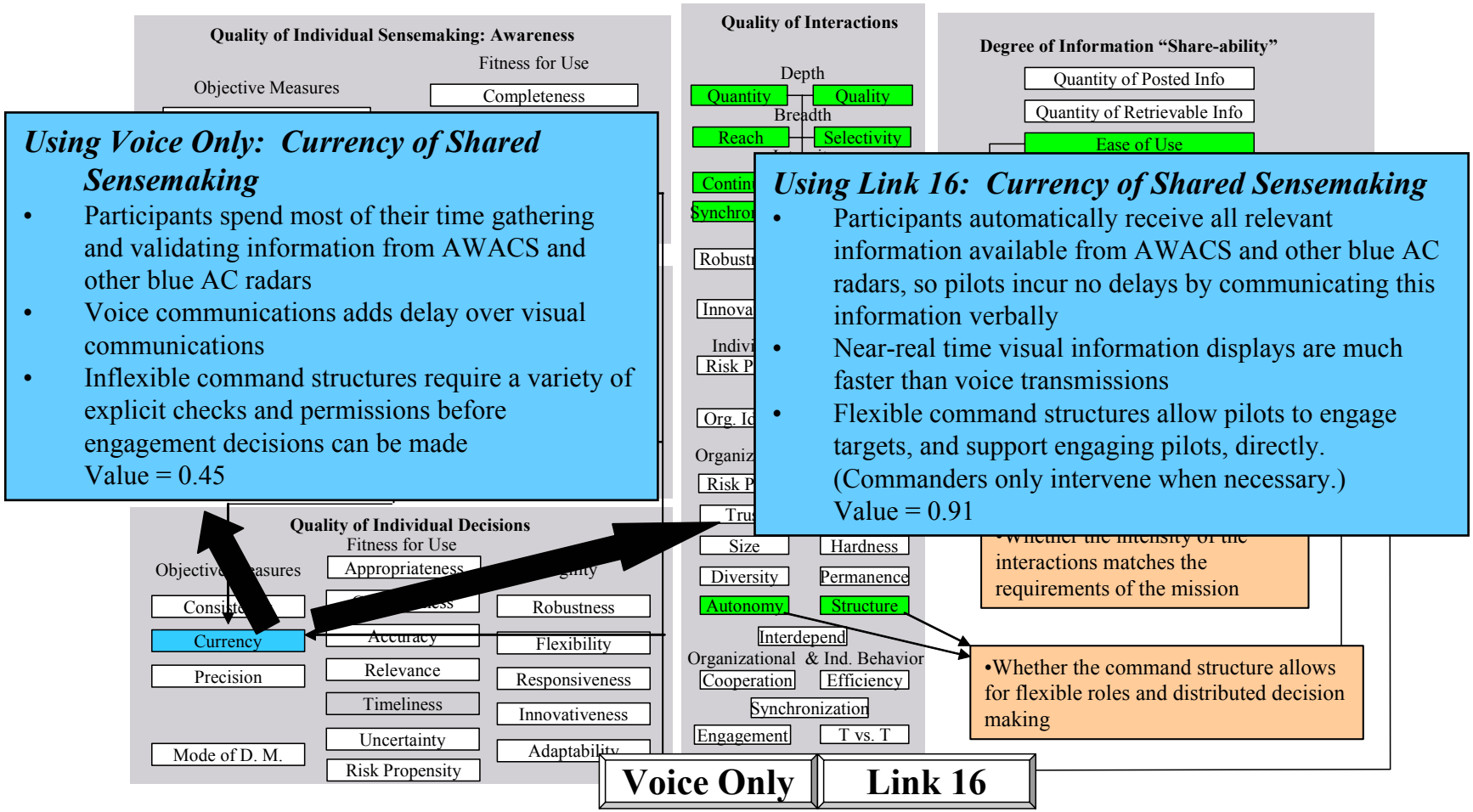
C2 Agility

es Synchronized

Force Agility

Degree of Effectiveness

Explanation of Degree of Shared Sensemaking Values

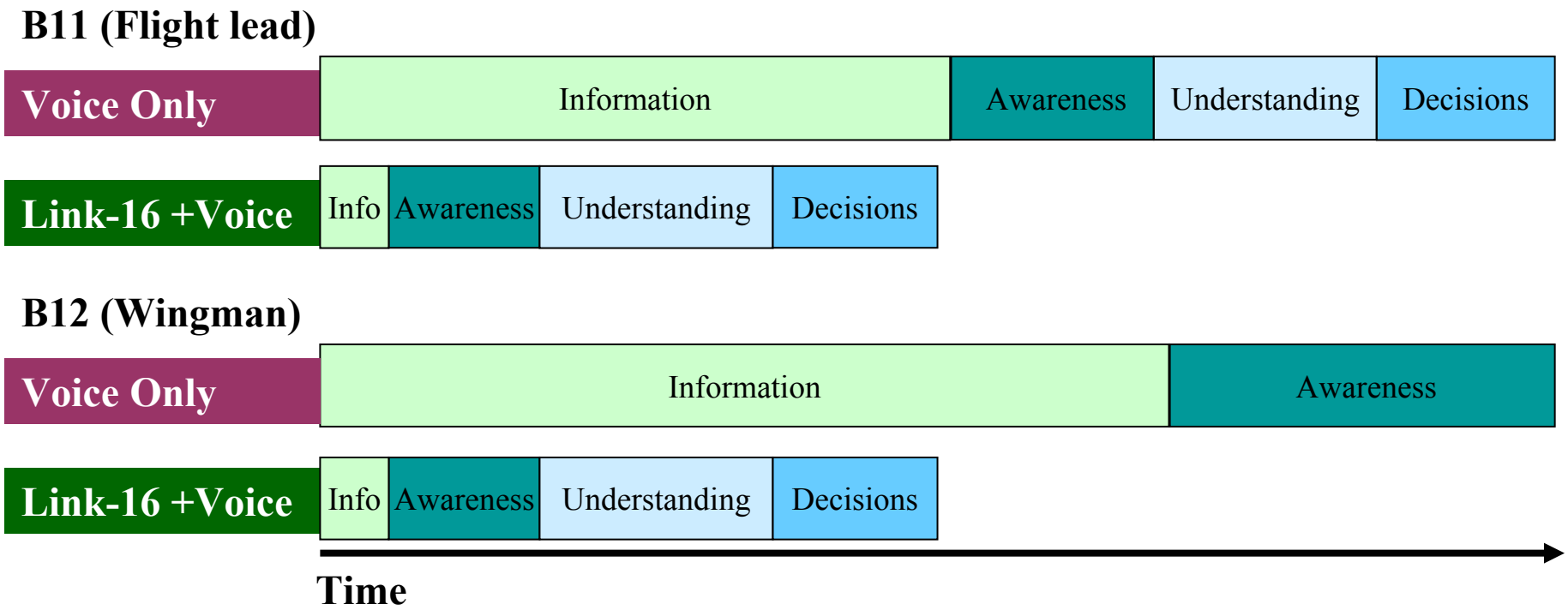


Degree of Shared Sensemaking (Currency)

Hypotheses:

I. Information sharing via Voice + Link 16 leads to less time necessary to gather critical information, which results in more time available for flight lead to develop sensemaking

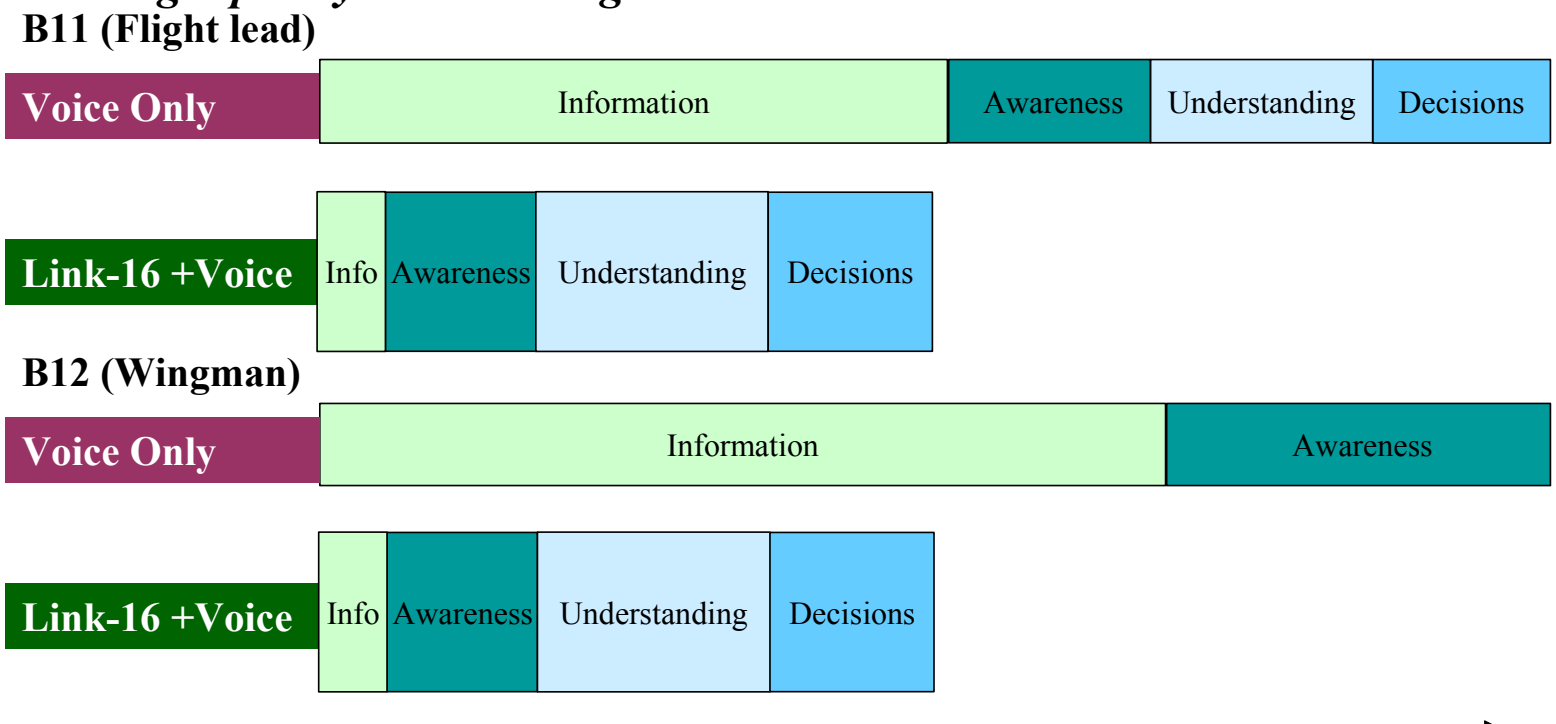
II. Information sharing via Voice + Link 16 leads to less time necessary for wingman to gather and monitor critical information, which results in opportunities for wingman to spend time sensemaking



Degree of Shared Sensemaking (Quality: Extent, Correctness)

Hypothesis: Information sharing via Voice + Link 16 leads to less time spent on information gathering, which results in more time available for flight lead and wingman to share awareness, understandings and make decisions, which results in an increase in the extent and correctness of sensemaking

Evidence: Interviews with pilots reveal that with Link 16 +Voice, voice communications traffic focused on sharing information decreased dramatically leaving more time to develop and share high quality sensemaking

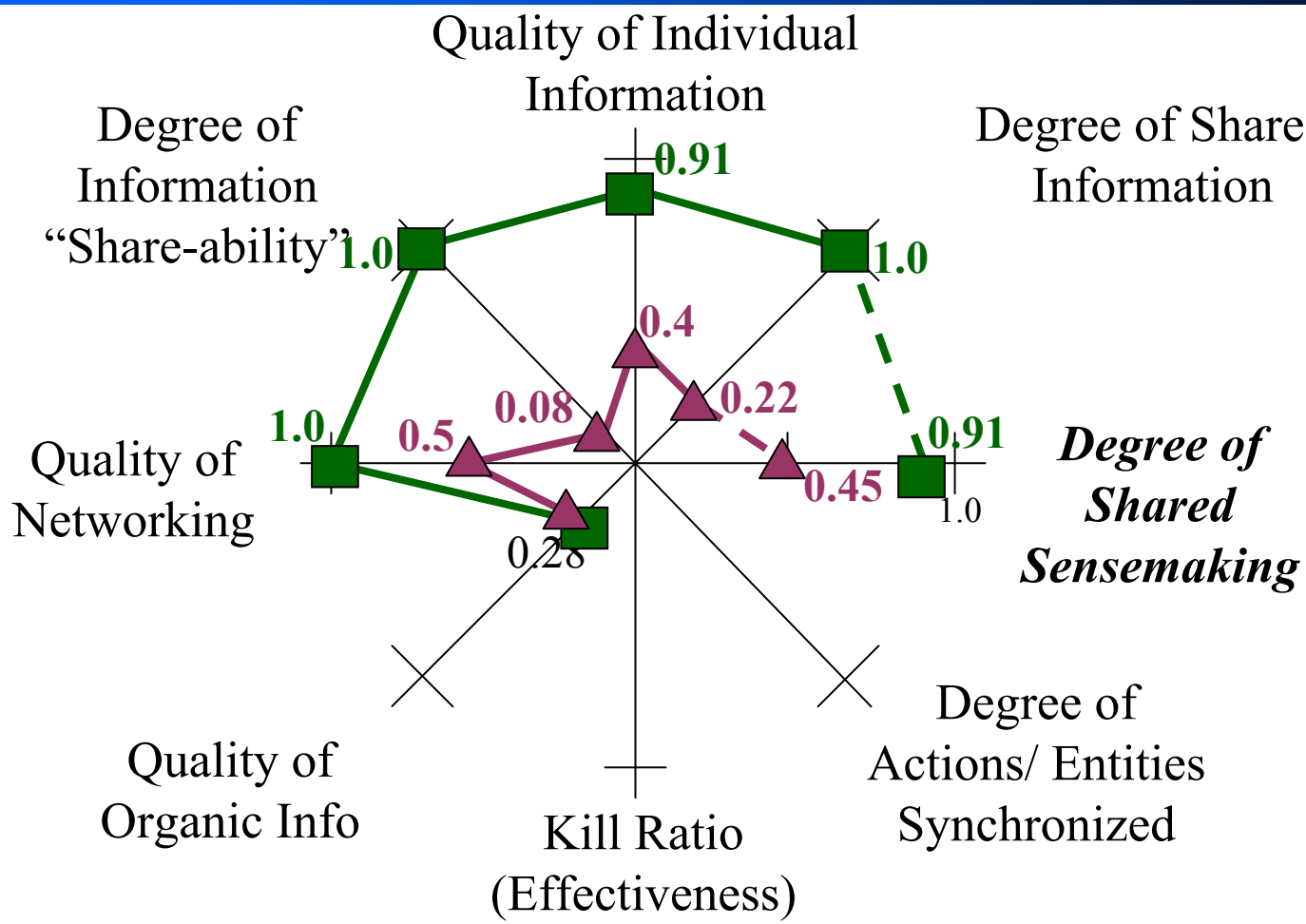


Degree of Shared Sensemaking

Attribute	Voice Only (0.45)	Link 16 (0.91)
Extent	Medium	High
Correctness	Medium	High
Consistency	Not Calculated	Not Calculated
Currency	Medium	High
Precision	Not Calculated	Not Calculated
Completeness	Not Calculated	Not Calculated
Accuracy	Not Calculated	Not Calculated
Relevance	Not Calculated	Not Calculated
Timeliness	Not Calculated	Not Calculated
Uncertainty	Not Calculated	Not Calculated

Note: The Values of NCO CF Variables and Attributes are Inferred

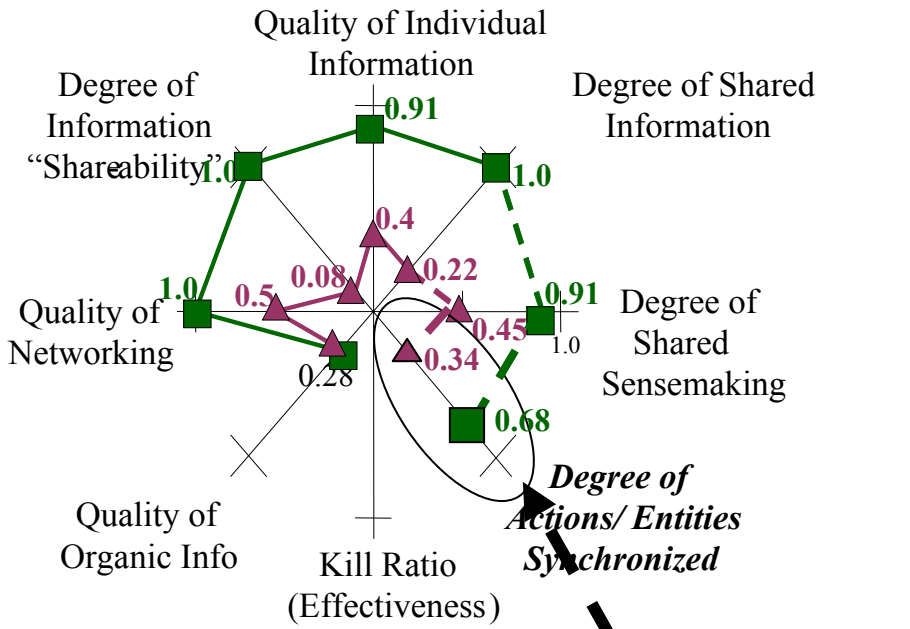
Degree of Shared Sensemaking



Overall average over information quality dimensions and package members

What We Know (Inferred): Degree of Actions/ Entities Synchronized

Information Sources | *Value Added Services* | Force | C2 | **Communication Capability**



Degree of Actions/ Entities Synchronized

Overall average over information quality dimensions and package members

Quality of Networking

Net Readiness of Nodes

Degree of Information "Share-ability"

Degree of Shared Information

Degree of Shared Sensemaking

- Shared Awareness
- Shared Understanding
- Collaborative Decisions

Degree of Decision/ Synchronization

C2 Agility

Degree of Actions/ Entities Synchronized

Force Agility

Degree of Effectiveness

Explanation of Degree of Actions/ Entities Synchronized Values

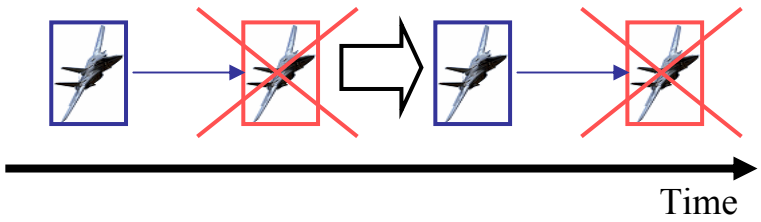
- Based on Interviews with Pilots and SMEs, it was Determined that Pilots with Link 16 Utilized Different Tactics
  - Four New Tactics Emerged (See Next Slide)
  - These New Tactics Were Employed Approximately 75% of the Time (Interview Results)
  - Value of Degree of Action/ Entities Synchronized:
    - Voice Only: 0.34
    - Voice + Link 16: 0.68

Degree of Actions/ Entities Synchronized

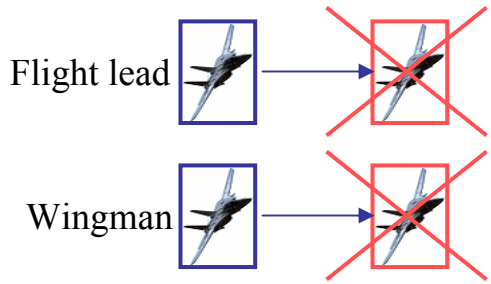
Reported Tactical Improvements Enabled by Voice + Link 16

Greater understanding and more time available allows for use of four types of "high-awareness" tactics that lead to major increases in combat effectiveness

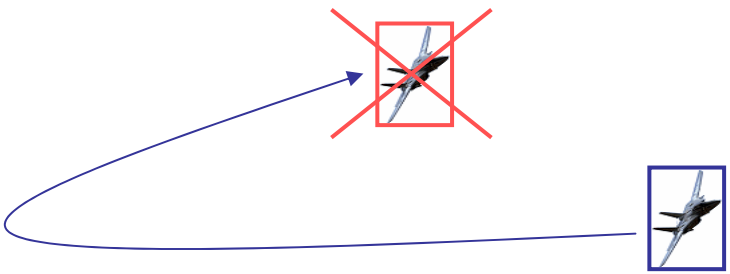
1. Increased numbers of engagements in the same time period



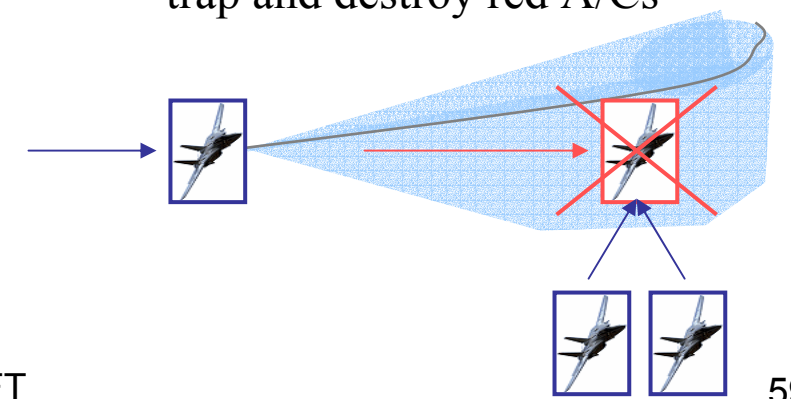
2. Employment of the wingman as combatant rather than defensive patroller



3. Advance vectoring to engage red A/Cs from position of maximum advantage



4. Employment of cooperative formations to trap and destroy red A/Cs

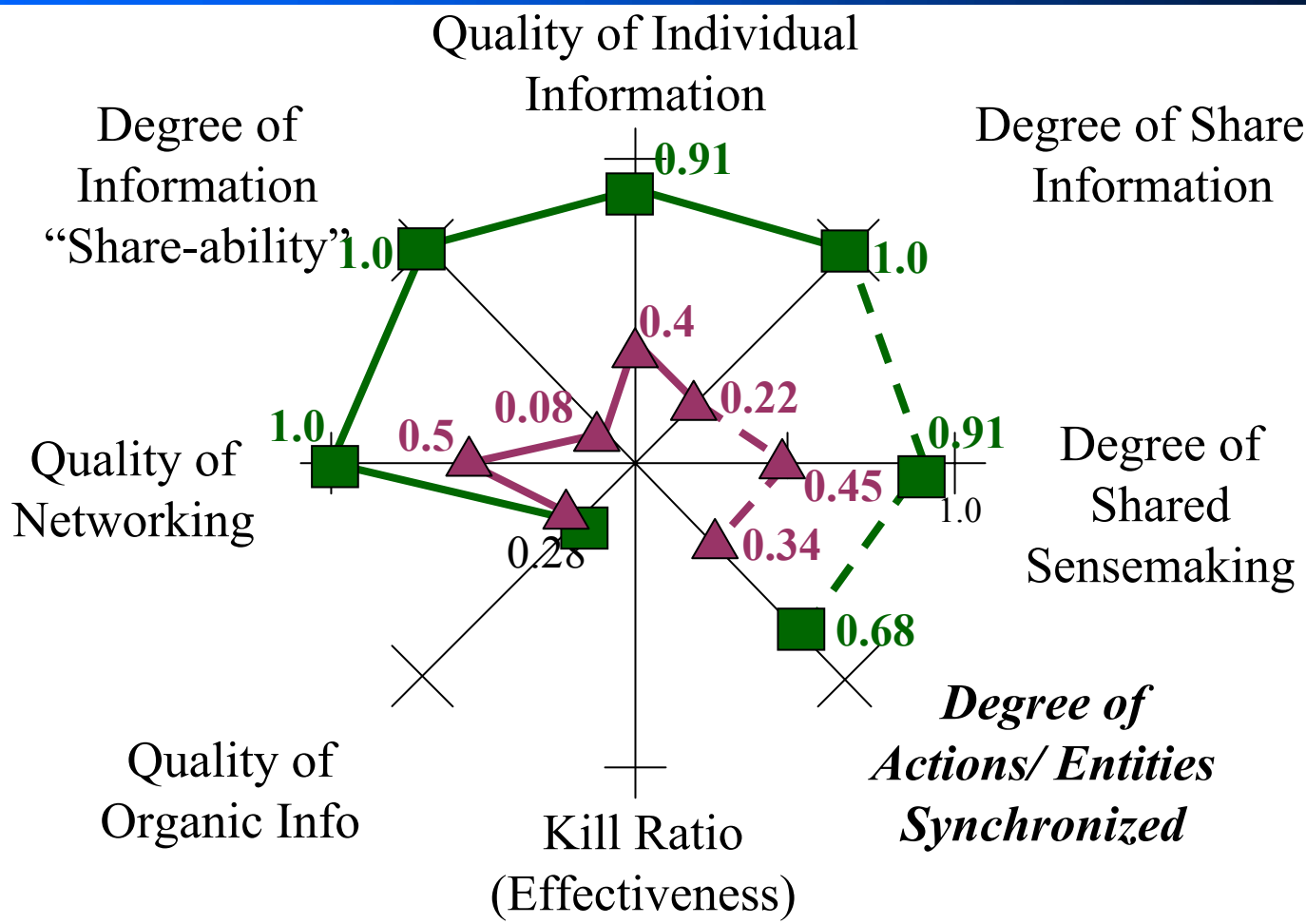


Degree of Actions/ Entities Synchronized

Attribute	Voice Only (0.34)	Link 16 (0.68)
Synchronized Actions	Medium	High
Synchronized Entities	Medium	High

Note: The Values of NCO CF Variables and Attributes are Inferred.

Degree of Decision/ Synchronization



Overall average over information quality dimensions and package members

What We Know (Inferred): Degree of Decision/ Synchronization

Information Sources | *Value Added Services* | Force | C2 | **Communication Capability**

Quality of Organic

Quality of Networking

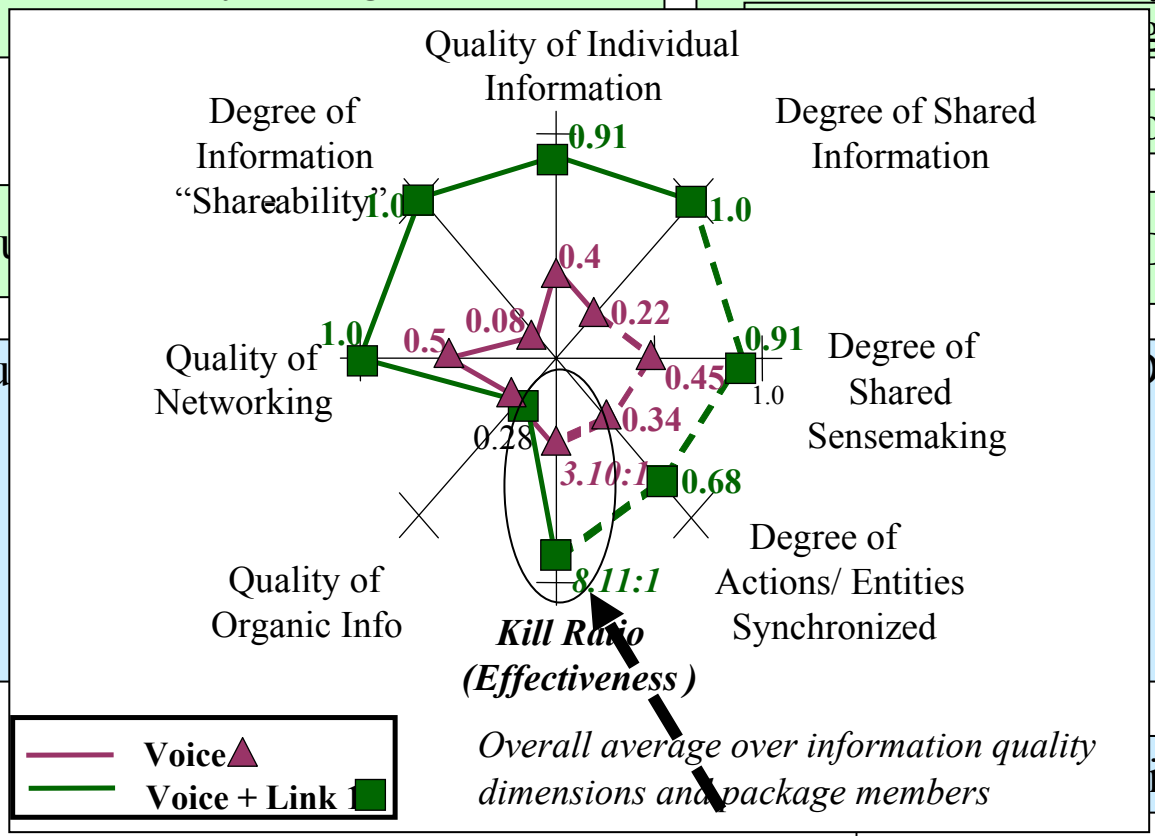
Net Readiness of Nodes

…rmation "Share-ability"

…Degree of Shared Information

…Degree of Shared Sensemaking

- Shared Awareness
- Shared Understanding
- Collaborative Decisions



…ion

C2 Agility

Force Agility

Degree of Actions/ Entities Synchronized

Degree of Effectiveness

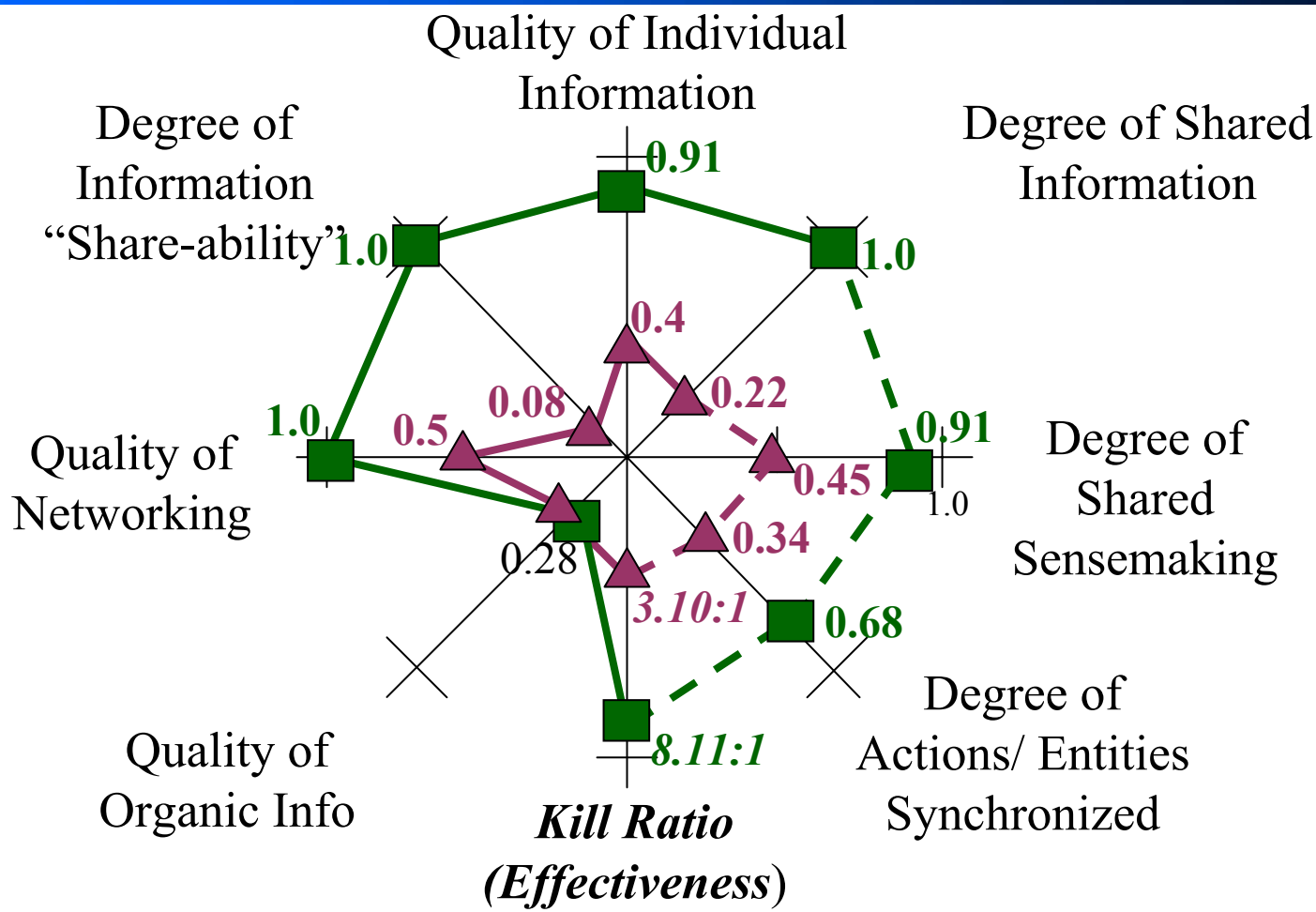
Degree of Effectiveness

Attribute	Voice Only	Link 16
Achievement of Objectives	Kill Ratio: 3.10 Day 3.62 Night	Kill Ratio: 8.11 Day 9.40 Night
Agility	Not Calculated	Not Calculated
Timeliness	Not Calculated	Not Calculated
Efficiency	Not Calculated	Not Calculated

Note: The Indicator of Achievement of Objectives is Kill Ratio. It is highly likely that other case studies will have multiple indicators of success. Also, not all attributes will be applicable for all case studies.

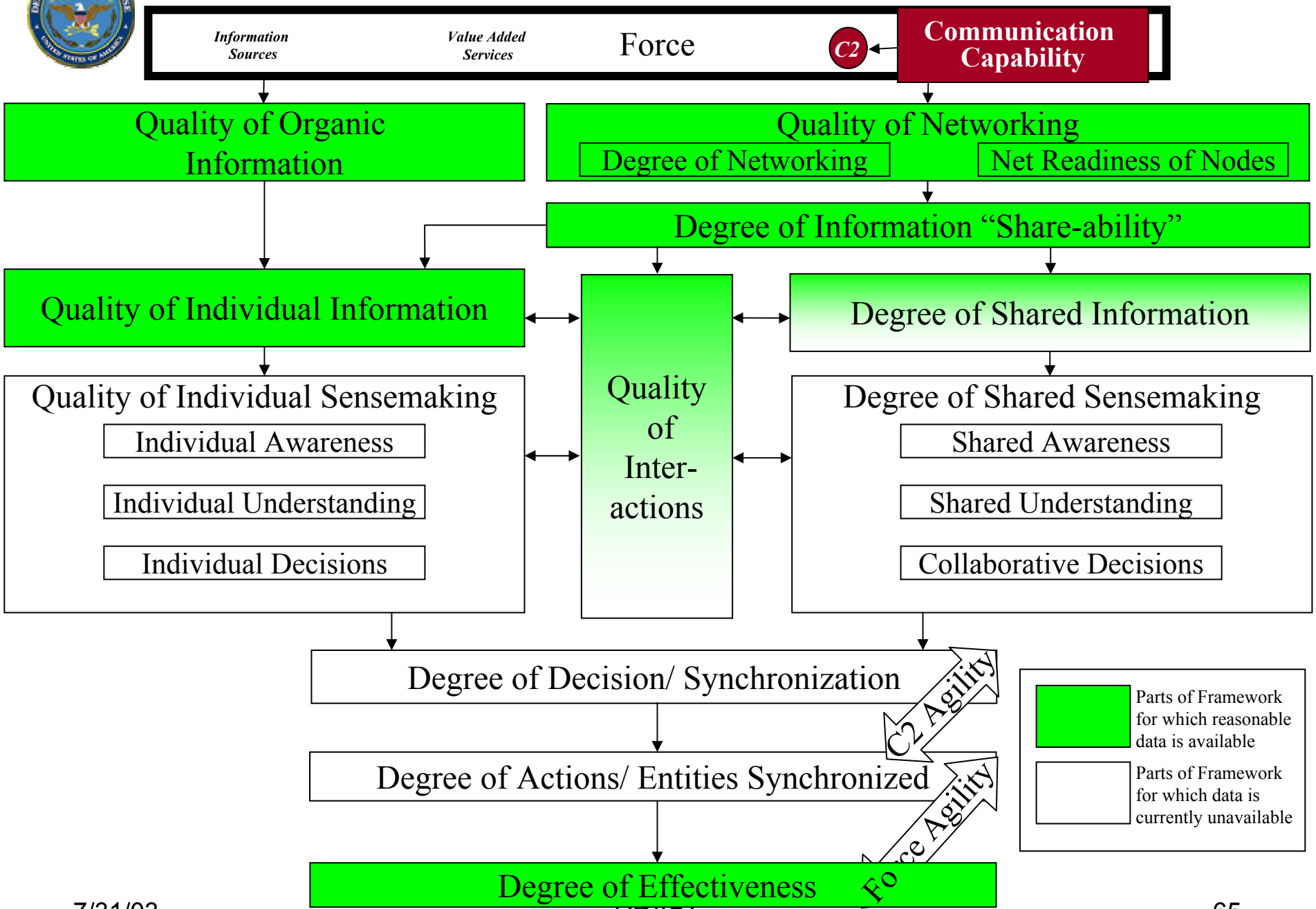
The values of the variable were provided in the original data and were not computed or inferred.

Degree of Effectiveness



Overall average over information quality dimensions and package members

Data Currently Available for Air-to-Air Example



Solution Strategy (3)

- Postulate a "Conceptual Model" (NCO "Story Line")
- Identify What We Know
- Identify What We Need to Know

Identify What We Need to Know

- What is the Resulting Impact on the Quality and Degree of Sensemaking, Quality of Interactions, and Synchronization?
- How Does the Addition of Link 16 Effect the Overall Mission Capability Package? (Are There Associated Changes in C2 and Tactics?)

Agenda

- Case Study Background
- The Bottom Line Result
- Problem Formulation
- Solution Strategy
- The Way Ahead

The Way Ahead:
Further Development of the Air-to-Air Case Study

- Research Plan to Complete Case Study
  - Additional Data Collection/Modeling/Analysis to Focus on:
    - Sensemaking
    - Quality of Interactions
    - Synchronization
  - Sources of Data: Interviews, Voice Tapes, Reports, etc.
  - Analysis Tools: Explore Use of Analytica, Others
- Execute and Update
  - Phase I (Air-to-Air Case Study Completed so Far): Networking/ Data Sharing
  - Phase II (Hypothetical Continuation of Air-to-Air Case Study): Sensemaking/ Synchronization (*To be Completed)*